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## ABSTRACT

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## USE OF HERBS FOR TREATMENT OF DIABETES MELLITUS

**Introduction:** Medicinal plants have been widely used in traditional medicine for their potential in managing diabetes mellitus by regulating blood sugar levels and improving overall metabolic health. As diabetes mellitus continues to be a global health problem, natural remedies derived from plants have attracted attention for their efficacy and fewer side effects compared to synthetic medicines. Many cultures traditionally rely on herbal remedies to treat diabetes-related symptoms, and modern research continues to validate these traditional practices.

**Methods:** The antidiabetic properties of medicinal plants are mainly attributed to their bioactive compounds, which include flavonoids, alkaloids, terpenoids, polyphenols and saponins. These substances contribute to blood sugar regulation through various mechanisms. Some plants increase insulin secretion from pancreatic beta cells, while others increase insulin sensitivity in peripheral tissues such as muscle and liver. Some medicinal plants prevent spikes in blood sugar by slowing the digestion and absorption of carbohydrates in the intestines. Moreover, some plants have antioxidant and anti-inflammatory properties, protecting pancreatic cells from damage and supporting their function.

**Results:** Scientific studies have shown that several medicinal plants effectively lower fasting blood glucose levels, improve glucose uptake by cells and reduce long-term glucose markers such as HbA1c. Some plants also contain soluble fibre that slows glucose absorption and improves glycaemic control. Moreover, some herbs have been shown to reduce inflammation, oxidative stress and insulin resistance, which are important factors in the progression of diabetes mellitus.

**Conclusions:** Although medicinal plants offer important benefits in the treatment of diabetes mellitus, their proper use, dosage and preparation methods should be carefully monitored. Possible interactions with conventional antidiabetic drugs should be taken into account and people should consult their doctor before incorporating herbal therapies into their routine.

**Keywords:** clinical trials, diabetes mellitus, disease treatment, medicinal herbs.

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## ВИКОРИСТАННЯ ТРАВ ДЛЯ ЛІКУВАННЯ ЦУКРОВОГО ДІАБЕТУ

**Вступ:** Лікарські рослини широко використовуються в традиційній медицині завдяки їхньому потенціалу в лікуванні цукрового діабету шляхом регулювання рівня цукру в крові та покращення загального метаболізму. Оскільки цукровий діабет залишається глобальною проблемою охорони здоров'я, натуральні засоби, отримані з рослин, привертають увагу своєю ефективністю і меншою кількістю побічних ефектів у порівнянні з синтетичними препаратами. Багато культур традиційно покладаються на рослинні засоби для лікування симптомів, пов'язаних з діабетом, і сучасні дослідження продовжують підтверджувати ці традиційні практики.

**Методи:** Антидіабетичні властивості лікарських рослин в основному пов'язані з їх біологічно активними сполуками, які включають флавоноїди, алкалоїди, терпеноїди, поліфеноли та сапоніни. Ці речовини сприяють регуляції рівня цукру в крові за допомогою різних механізмів. Деякі рослини збільшують секрецію інсуліну бета-клітинами підшлункової залози, а інші підвищують чутливість до інсуліну в периферичних тканинах, таких як м'язи та печінка. Деякі лікарські рослини запобігають стрибкам рівня цукру в крові, сповільнюючи перетравлення та всмоктування вуглеводів у кишечнику. Крім того, деякі рослини мають антиоксидантні та протизапальні властивості, захищаючи клітини підшлункової залози від пошкодження та підтримуючи їхню функцію.

**Результати:** Наукові дослідження показали, що деякі лікарські рослини ефективно знижують рівень глюкози в крові натще, покращують поглинання глюкози клітинами і знижують довгострокові маркери глюкози, такі як HbA1c. Деякі рослини також містять розчинну клітковину, яка уповільнює всмоктування глюкози та покращує контроль глікемії. Крім того, деякі трави зменшують запалення, окислювальний стрес та інсулінорезистентність, які є важливими факторами прогресування цукрового діабету.

**Висновки:** Хоча лікарські рослини пропонують важливі переваги в лікуванні цукрового діабету, їх правильне використання, дозування і методи приготування повинні ретельно контролюватися. Слід враховувати можливі взаємодії зі звичайними ліками від цукрового діабету, а також проконсультуватися з лікарем перед тим, як включати фітотерапію у свій щоденний раціон.

**Ключові слова:** клінічні випробування, цукровий діабет, лікування захворювання, лікарські трави.

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## INTRODUCTION

Given the global current presence of this disease, knowing how to manage diabetes mellitus effectively is more important than ever. Untreated, this chronic condition may lead to serious complications. Medicinal plants have attracted much attention in recent years, thanks to their known antidiabetic, hypoglycemic and antihyperglycemic properties, and are widely used in supplementation to traditional medicine for the management of diabetes mellitus. In addition to their efficacy, affordability, and accessibility, these medicinal plants, then, are particularly significant for diabetes mellitus management.

Genes and the environment influence diabetes mellitus development. It arises from either increased insulin insensitivity or impaired insulin action in target tissues, which leads to abnormal metabolization of sugars in the body. This is where a lack of insulin production in pancreas or inadequate use of insulin in body leads to damaging, dysfunctional, and failure of multiple organ systems (heart, blood vessels, eyes, kidneys, and nerves) and causes type 2 diabetes and its comorbidities, disability, and early death [1].

Patients with type 1 diabetes are susceptible to ketoacidosis and require daily insulin injections to manage their blood glucose levels. Type 2 diabetes accounts for the majority of cases globally due to the body's ineffective use of insulin leading to hyperglycemia. Risk factors include ethnicity, family history, previous gestational diabetes mellitus, older age, overweight and obesity, unhealthy diet, physical inactivity, and smoking.

Type 2 diabetes mellitus (T2DM) poses a significant global health and economic challenge, influenced by genetic and lifestyle factors. The global community actively seeks cost-effective and powerful drugs for T2DM to reduce annual fatalities. Many antidiabetic drugs require ongoing, lifelong use, causing side effects like diarrhea, abdominal distention, and flatulence. The pursuit of cost-effective, low-side-effect antidiabetic treatments has led to the investigation of medicinal plants [2].

Diabetes mellitus is a persistent metabolic condition characterized by elevated blood sugar levels. Prolonged glucose elevation harms body tissues, leading to disabling and life-threatening complications (blindness, nephropathy, neuropathy, diabetic foot, cardiovascular issues, and stroke). 90-95% of all diabetes cases are

Type 2 diabetes mellitus (T2DM), making it a primary area of diabetes research. Insulin sensitivity worsens, requiring more insulin to maintain normal blood sugar levels. Dysfunction of pancreatic beta-cells is another diagnostic factor for T2DM. In its initial phase, peripheral tissues become insulin resistant, causing pancreatic islet cells to upregulate insulin secretion as compensation [2].

Consumption of several natural products, including numerous plant-specific metabolites, could potentially decrease T2DM risk due to their insulin-mimetic or secretagogue effects that improve glucose metabolism. Over 400 plant species have been reported as antihyperglycemic. To prevent Type 2 Diabetes, promoting an active lifestyle and a nutritious diet is essential given the influence of unhealthy habits on its development. The intake of natural products, especially plant-specific metabolites, can lower the risk of T2DM. These studies focusing on natural remedies often replicate previous results and lack new insights, with clinical trials often featuring limited subjects and short-term goals. The translation of bench research to clinical use remains challenging, and the role of natural remedies in everyday life has yet to be definitively established [3].

Traditional medicine has substantial experience and prescriptions for diabetes mellitus treatment, focusing on the antidiabetic properties of utilized plants and their  $\alpha$ -glucosidase-inhibiting phytoconstituents. Despite the success of some medicines in regulating postprandial blood glucose, they are associated with significant gastrointestinal side effects, contributing to widespread medication noncompliance. Researchers seek effective alternatives with minimal side effects. Herbal chemicals offer milder techniques for controlling metabolic problems and have been used in traditional medical systems like Indian Ayurveda, Chinese herbal medicines, and Arabic Unani. Numerous medicinal herbs can be beneficial in managing T2D [4].

Diabetes mellitus and its complications have been addressed through various therapeutic methods, including traditional medicine and the development of new medicines. Numerous medical plants have been associated with various mechanisms underlying diabetes mellitus.

Natural products, particularly those of plant origin, play an imperative role in drug development programs, serving as the main sources of promising lead

candidates. In rural areas, plant-based therapies are more accessible, cost-effective, and have fewer side effects, making them the primary choice for treatment. These plants offer a wealth of bioactive substances, void of unwanted side effects, that exert potent therapeutic effects. Many medicines originate from plants, produced directly or indirectly from them. The review by Durazzo et al. summarizes the current state of research on plant-derived bioactive compounds, covering botanical characteristics, study definitions, and cutting-edge discoveries, and promotes the importance of categorizing botanicals as valuable resources in health research.

For centuries, many plants have been considered fundamental sources of potent antidiabetic drugs. In developing countries, medicinal plants are particularly used to treat diabetes mellitus to overcome the cost burden of conventional medicines. Currently, treatments for diseases, including diabetes mellitus, using medicinal plants are recommended due to their various phytoconstituents (such as flavonoids, terpenoids, saponins, carotenoids, alkaloids, and glycosides) which possess antidiabetic activities. The combined action of biologically active compounds (polyphenols, carotenoids, lignans, coumarins, glucosinolates, etc.) leads to the potential beneficial properties of each plant matrix [1].

Globally, herbal remedies and non-toxic plant extracts are notable alternatives for diabetes mellitus treatment due to their insignificant toxicity and absent side effects. Antidiabetic medicinal plants can be effective alternatives to pharmaceutical medicines for diabetes mellitus treatment. Diabetes mellitus management benefits from medicinal plants with hypoglycemic effects. Ríos et al. discussed antidiabetic medicinal plants (e.g., aloe, banaba, bitter melon, caper, cinnamon, cocoa, coffee, fenugreek, garlic, guava, gymnema, nettle, sage, soybean, green and black tea, turmeric, walnut, and yerba mate) and their high-interest compounds (e.g., fukugetin, palmatine, berberine, honokiol, amorfrutins, trigonelline, gymnemic acids, gurmardin, and phlorizin) used for treating diabetes mellitus and its comorbidities [2].

Approximately 410 medicinal plants have been identified as having antidiabetic properties based on experimental evidence. These compounds, such as tannins, alkaloids, flavonoids, and phenolics, are abundant in medicinal plants and are vital for enhancing pancreatic tissue functionality through control of intestinal glucose absorption and insulin secretion. Medicinal plants offer an affordable alternative therapy option for diabetes mellitus treatment [2].

A medicinal plant is any plant containing therapeutic compounds in its parts or organs. Phytochemicals, naturally occurring chemical compounds with beneficial health effects, are abundant in fruits, vegetables, plant-based beverages, and cereal grains, accumulating primarily in the outer layers of plant parts.

Considering the effectiveness of herbal medicines in relieving diabetic complications, evaluating and identifying the active components of plants is rapidly becoming an interesting goal for diabetes mellitus treatment in clinical trials. Polyphenols, carbohydrates, flavonoids, and other biomolecules from herbs are the key active components responsible for disease treatment. This review examines the clinical trial evidence for the diabetes mellitus treatment benefit of carbohydrates in medicinal herbs.

#### MATERIALS AND METHODS

Electronic databases including PubMed, Google Scholar, and Wiley. Online library were searched using general keywords such as “antidiabetic”, “medicinal herbs”, “diabetes”, “glycemic index”, and “clinical trial”. Only papers published after the year 2019 with full English text were included.

#### RESULTS AND DISCUSSION

Medicinal plants have been widely researched as an alternative approach for healing, treating, and managing diseases, providing both cost-effectiveness and minimal side effects. This review focuses on easily accessible medicinal plants recognized for their effectiveness in managing diabetes mellitus with limited adverse effects (Table 1).

*Melissa officinalis* L., or lemon balm, belongs to the Lamiaceae family and is a notable source of flavonoids, which have been found to help lower fat levels and blood sugar. Research has identified that lemon balm is rich in phenolic and flavonoid compounds like rosmarinic acid and caffeic acid, which are known for their antioxidant, antidiabetic, and blood pressure-lowering effects [5]. Several studies in animals and cell cultures have highlighted *M. officinalis*'s ability to reduce blood sugar and lipids prevent glycation, and inhibit pancreatic amylase. Clinical research has also shown its effects on lowering lipids, reducing inflammation, and enhancing antioxidant activity [6-8].

Some studies showed that *M. officinalis* supplementation improved fasting blood sugar, HbA1c, and systolic blood pressure, reduced triglycerides, and increased HDL-c in individuals with type 2 diabetes mellitus, with no significant side effects. Additionally, *M. officinalis* exhibited antioxidant and anti-inflammatory effects, suggesting cardiovascular benefits for diabetics mellitus [9].

Table 1 – Recent clinical trials involving herbal medicines

Herbs	Patient groups	Dosage	Follow-up	Outcome of Intervention	References
Abelmoschus esculentus - Okra whole fruit	okra group n = 60 control group n = 60	1,000 mg of A.esculentus whole fruit capsules orally, every 6 hr	56 days	The levels of FBS, BS, and HgA1c were significantly decreased in okra group within the intervention compared to control group (p < .05).	[13]
Abelmoschus esculentus (L.) Moench - okra fruit	okra fruit group n=50 placebo group n=50	1000 mg of powdered okra fruit three times a day other group received a placebo capsule with the same dosage	3 months	improves lipid profile, glycemic control, and chronic inflammation without any tangible adverse effects	[14]
Melissa officinalis hydroalcoholic extract	intervention group n = 30 control group n=30	received 700 mg/day hydroalcoholic extract received 700 mg/day toasted flour	12 weeks	there was a significant decrease in depression and anxiety severity(p < 0.001 and p = 0.01, respectively) at the end of the study compared to the baseline.	[15]
Trigonella foenum-graecum seed powder solution	treatment group n = 57 control group n = 57	25 g Trigonella foenum-graecum seed powder solution orally twice a day second group is the receives metformin	1 month	Trigonella foenum-graecum seed powder solution had pronounced effects in improving lipid metabolism in type II diabetic patients with no adverse effects.	[16]
artichoke leaf extract supplement	metformin-vitamin E (ME) groups metformin-ALES (MA) groups vitamin E-ALES (EA) groups	oral administration of 1,000 mg/day of metformin in two divided doses (every 12 hr) plus vitamin E (400 UI/day); oral administration of 1,000 mg/day of metformin in two divided doses (every 12 hr) plus 800 mg/day of ALES in two divided doses (every 12 hr) ; oral administration of 800 mg/day of ALES in two divided doses (every 12 hr) plus vitamin E (400 UI/day).	12 weeks	the rate of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) was significantly reduced; the rate of fat accumulation in liver of patients was decreased significantly within all the study groups; increased in the subjects with grade 0 fatty liver (without fat accumulation) in the MA and EA groups by 23.3 and 17.2%, respectively.	[17]
Herbal capsule: Capparis spinosa -170 mg Rosa canina -225 mg Securidaca securigera -170 mg Silybum marianum -65 mg Urtica dioica -170 mg Trigonella foenum-graecum -115 mg Vaccinium arctostaphylos (85 mg) extracts (1000 mg) in two capsule. Metformin capsules: filled with 250 mg of metformin mixed with toasted powder. Placebo capsules:filled with toasted powder.	herbal combination n=50; metformin groups n=50; placebo groups n=50	each group received either herbal combination or placebo or metformin capsule daily	90 days	the fasting plasma glucose, HbA1c and cholesterol levels in herbal combination were decreased significantly as compared to placebo group (20% and 12% respectively) and also compared to base line (25% and 15% respectively).  anti-hyperglycemic effects of the traditional herbal combination used in study is superior to placebo and effective as metformin (500 mg), as a hypoglycemic agent in patients with diabetes mellitus type II who are also on oral hypoglycemic agents.	[18]

Herbs	Patient groups	Dosage	Follow-up	Outcome of Intervention	References
combination of oxymel and Zataria multiflora Boiss.	Group A received; group B received; group C (control)	0.75 g ZM in 10 mL oxymel in each treatment; group B received 1.5 g ZM in 10 mL of oxymel in each treatment group C (control) only received 10 mL of oxymel in each treatment	3 months	treatment with ZO and oxymel reduced insulin resistance, and waist and hip circumferences in overweight patients.	[19]
aqueous leaves extract of Coccinia grandis (Linn.) Voigt (Cucurbitaceae)	herbal drug groups n = 79 placebo drug groups n = 79	receive 500 mg once daily	3 months	Treatment with herbal drug of C. grandis (500 mg per day) for three months for patients with newly diagnosed T2DM significantly improved their glycemic and selected lipid profile parameters with well tolerated safety.	[20]
fenugreek plant (Trigonella foenum-graecum)	treatment group n= 42 placebo group n=39	1,000 mg (500 mg × 2)	12 consecutive weeks	After 12 weeks of administration, both fasting as well as postprandial serum glucose levels decreased by 38 and 44% respectively in the treatment group. Simultaneously, a significant reduction in glycated hemoglobin by about 34.7% was also noted.	[21]
contents of one capsule are 300 mg Mas Cotek + 100 mg Cinnamomum cassia L. + 250 mg Nigella sativa L. powdered extracts	double-blind, double-dummy, randomized, active-controlled, parallel-group	metformin (2000 mg per day), low-dose NW Low-Glu® (content of four capsules per day), or high-dose NW Low-Glu® (content of five capsules per day).	12-week	After 3 months of treatment, NW Low-Glu® was noninferior to metformin in reducing HbA1c and 2 hr PPG, while leading to significantly higher weight reduction in newly diagnosed T2DM patients.	[22]
bread enriched with Portulaca Oleracea	intervention group, control group	bulk bread containing 10% Portulaca powder, normal daily bread	4 weeks	improvement lipid profile	[23]
cinnamon supplementation	Group1 (Cinnamon), Group2 (Placebo)	to take either a cinnamon or a placebo capsule two times a day (2g/day)	60 days	consumption 2 g/day of cinnamon reduced the mean fasting serum glucose to (– 11.7 % and – 35.5%), triglyceride (– 21.9 % and – 23.4%), total cholesterol (–31.52% and –24.29%), SBP (–10.86% and – 17.7%) and DBP was reduced to (- 4.1% and -0.22%) for female and male respectively.	[24]
pumpkin seed extract, gum Arabic and vildagliptin	control nondiabetic, control non-treated diabetic, diabetic treated with a combination of pumpkin seed extract and vildagliptin, and diabetic treated with a combination of gum Arabic and vildagliptin	pumpkin seed extract (300 mg/kg/day), gum Arabic (500mg/kg/day), vildagliptin (10mg/kg/day),	12 weeks	can alleviate the severity of hyperglycemia, insulin resistance, dyslipidemia and depress glucagon secretion	[25]

Herbs	Patient groups	Dosage	Follow-up	Outcome of Intervention	References
baobab plant ( <i>Adansonia digitata</i> ) and metformin	Control group, Group with Baobab, Group with metformin	The control group received alloxan monohydrate, the group with Baobab received 500 mg/kg orally, the group with metformin received 100 mg/kg orally	15 and 30 days	D.M. in male rats increased kidney function markers and hepatic enzymes, but baobab plant treatment reduced these levels, indicating potential to mitigate adverse effects and increase beneficial fat levels.	[26]
<i>Vigna radiata</i> (L.) Wilczek seeds	Normal Control (n = 6) Standard Drug (n = 6) Extract (n = 6) Extract (n = 6) Extract (n = 6)	Group NC, 10 ml/kg NS, Group SD, Glibenclamide (5 mg/kg), Group VR100, 100 mg/kg, Group VR200, 200 mg/kg, Group VR400, 400 mg/kg	14 days	The methanol extract of <i>V. radiata</i> seeds also moderated lipid profiles, AST, ALT, and glycated hemoglobin while restoring liver glycogen and insulin levels in diabetic mice, suggesting its potential advantages in reducing some of the consequences of diabetes mellitus.	[27]

*Trigonella foenum-graecum* or Fenugreek seeds are rich in bioactive compounds like alkaloids, saponins, and soluble fiber, contributing to their antidiabetic properties. These compounds help improve insulin sensitivity, reduce insulin resistance, and enhance glucose metabolism, leading to lower blood glucose levels in both animal and human studies. Fenugreek also has antioxidant and anti-inflammatory effects, which may help reduce oxidative stress and inflammation in diabetic individuals. Clinical trials show that fenugreek supplementation improves fasting blood glucose levels, HbA1c, and lipid profiles [10]. Fenugreek has been found to be effective in regulating blood glucose by improving insulin sensitivity and reducing resistance. Fenugreek also inhibits enzymes like  $\alpha$ -amylase and maltase, which reduce glucose absorption [11].

*Rosa canina* L., also known as rose hip, has been traditionally used to treat various health issues, including inflammatory disorders, gastrointestinal problems, colds, kidney conditions, and especially diabetes mellitus. Recent studies have demonstrated the fruit's hypoglycemic effects. In animal models, *Rosa canina* significantly reduced blood glucose levels, especially in diabetic rats induced with streptozotocin. However, no direct correlation was found between high phenolic content and antidiabetic activity in certain other fractions [12].

*Securigera securidaca*. The studies investigate the hypoglycemic effects of *Securigera securidaca*, a plant traditionally used for diabetes mellitus management in Iranian and Indian folk medicine. In one study, both chloroform and methanol extracts were tested on streptozotocin-induced diabetic mice. The methanol extract at lower doses and the chloroform extract at higher doses showed comparable hypoglycemic effects to standard antidiabetic drugs like glibenclamide and

insulin. Cardiac glycosides, isolated as the active compounds, appeared to stimulate insulin secretion, achieving blood glucose reductions similar to those in non-diabetic animals [28].

Another study using aqueous extracts on diabetic rats observed significant reductions in blood glucose after 7 and 14 days. Although blood lipid profiles remained unchanged, enzyme levels were elevated in the treated group, suggesting some liver-related side effects [29].

A final study confirmed the hypoglycemic effect of aqueous *S. securidaca* extract on diabetic rats but noted no impact on normoglycemic rats, suggesting a diabetes-specific action [30].

*Silybum marianum*. Research suggests that silymarin, a key compound from milk thistle, shows potential benefits for blood glucose regulation in T2DM, though evidence on its impact on lipid profiles remains inconclusive. Silymarin, composed of four main flavonolignans, has notable anti-inflammatory, antioxidant, and immune-modulating properties [31].

Additionally, milk thistle seed extract may inhibit glycation and enzymatic activity related to glucose metabolism, with effects on body weight, serum glucose, and cholesterol levels in animal studies. Further studies explore silymarin's benefits for other conditions, such as fatty liver and hepatitis, but more robust evidence is needed for definitive conclusions [32].

*Vigna radiata* L. the mung bean, also known as Oregon pea or mung, is a nutrient-rich legume historically cultivated in India and now widely grown in Asia, Africa, the West Indies, and the U.S. It thrives in well-drained soils and tolerates drought but is susceptible to waterlogging. Research suggests that *V. radiata* has notable antioxidant, antihyperglycemic, and anti-inflammatory properties, making it a candidate for

managing diabetes mellitus and its complications. Its low glycemic index and high protein and fiber content make it a functional dietary option for reducing blood sugar levels and oxidative stress [33]. While prior studies highlight its medicinal potential, especially in reducing oxidative stress and managing DM, further research is needed to solidify its role as a therapeutic agent. Mung beans hold promise as a basis for new antidiabetic drugs and functional foods aimed at preventing hyperglycemia and type 2 diabetes [34].

The use of herbal medicines, including *Nigella sativa* (black seeds), is prevalent among diabetes mellitus patients, with studies showing 7.3% of Jordanian diabetic patients using it for management. *N. sativa*, from the Ranunculaceae family, has long been used in traditional systems like Unani, Ayurveda, and Chinese medicine to treat chronic conditions, including diabetes mellitus, hypertension, and obesity. Its primary active constituent, thymoquinone, along with other bioactive compounds, contributes to its therapeutic effects [35].

Numerous clinical and animal studies highlight *N. sativa*'s antidiabetic potential through mechanisms such as improving insulin sensitivity, stimulating insulin secretion, reducing hepatic glucose production, enhancing glucose uptake, and mitigating oxidative stress. These properties make it a promising adjuvant therapy for managing type 2 diabetes, potentially reducing reliance on modern medications and minimizing side effects. Various *N. sativa* preparations have demonstrated significant efficacy in improving glucose tolerance, normalizing blood sugar and lipid levels, and protecting pancreatic  $\beta$ -cells [36, 37].

*Portulaca oleracea* (purslane), an annual succulent herb from the Portulacaceae family, is a globally distributed plant valued for its medicinal and nutritional properties. Recognized as a "Global Panacea" by the World Health Organization, purslane is rich in phytochemicals like polysaccharides, flavonoids, alkaloids, and omega-3 fatty acids, along with vitamins A and C, which contribute to its antioxidant, anti-inflammatory, antibacterial, and antidiabetic effects.

It regulates lipid and glucose metabolism, reduces blood glucose, improves insulin sensitivity, and protects pancreatic  $\beta$ -cells, suggesting its role in preventing diabetes mellitus complications such as vascular inflammation and nephropathy. The polysaccharides in purslane also improve blood lipid profiles and reduce oxidative stress in diabetic models [38, 39].

*Coccinia grandis* L. Voigt (Cucurbitaceae), widely used in traditional medicine in India and Sri Lanka, has demonstrated promising antidiabetic properties. All parts of this plant contribute to its efficacy through mechanisms such as pancreatic  $\beta$ -cell regeneration,

enhanced insulin secretion, improved glucose uptake, modulation of metabolic enzymes, restoration of antioxidant enzymes, lipid profile improvement, and inhibition of digestive enzymes [40].

The combination of *C. grandis* with other medicinal plants, such as *Blumea balsamifera*, shows synergistic effects, enhancing glucose-lowering efficacy and reducing side effects [41].

*Zataria multiflora* exhibits potent antioxidant and antidiabetic properties, making it a promising candidate for managing diabetes mellitus and associated oxidative stress. The essential oil of *Z. multiflora* (ZMEO) has demonstrated significant in vitro and ex vivo effects, including inhibition of glucose, lipid, and protein oxidation, as well as protein glycation. The dendrosomal formulation of ZMEO enhances its stability in biological fluids and its therapeutic efficacy. The primary bioactive components of ZMEO, carvacrol, p-cymene, and thymol contribute to its antioxidant and nitric oxide-scavenging properties, mitigating damage to the pancreas and liver. These findings suggest that *Z. multiflora* can protect against diabetic complications by reducing oxidative stress and improving glucose metabolism, with potential for clinical application in diabetes mellitus therapy [42].

*Capparis spinosa* L. (*Caper*), a perennial shrub from the Capparidaceae family, demonstrates promising antidiabetic properties alongside its traditional uses in managing various health conditions. The antidiabetic mechanisms of *C. spinosa* include reducing carbohydrate absorption, inhibiting gluconeogenesis, enhancing tissue glucose uptake, and protecting or regenerating pancreatic beta cells. Experimental findings also suggest that *C. spinosa* improves insulin sensitivity in peripheral tissues and decreases basal endogenous glucose production, as shown through advanced techniques like euglycemic-hyperinsulinemic clamps [43]. In addition to its antihyperglycemic and hypolipidemic effects, *C. spinosa* has been shown to mitigate complications of diabetes mellitus, such as cardiovascular disorders, liver damage, and nephropathy, primarily due to its antioxidant properties.

*Vaccinium arctostaphylos* L. (Caucasian whortleberry), a fruit-rich in anthocyanins, demonstrates potential benefits for managing type 2 diabetes and its associated complications. Traditionally used in regions such as Iran, Turkey, and the Caucasus to treat diabetes mellitus and hypertension, its fruit is also consumed as food [44]. Clinical studies indicate that a hydroalcoholic extract of whortleberry significantly lowers fasting glucose, postprandial glucose, and HbA1c levels in type 2 diabetic patients without adverse effects on liver or kidney function. While the leaf and fruit extracts have shown promising antihyperglycemic effects, their

impact on markers such as insulin levels and comprehensive safety profiles requires more research. The efficacy, safety, and phytochemistry of whortleberry warrant further investigation to validate its therapeutic role in diabetes mellitus management and related comorbidities [45].

*Urtica dioica* L., commonly known as stinging nettle, is a perennial plant from the Urticaceae family, widely distributed across Europe, North America, Asia, and North Africa. Nettle contains numerous bioactive compounds, including formic acid, acetylcholine, histamine, flavonoids, saponins, phytosterols, tannins, proteins, and amino acids, all contributing to its health benefits. Nettle has also been used in folk medicine to treat a wide range of ailments, including anemia, internal bleeding, gastrointestinal disorders, skin conditions, arthritis, gout, influenza, and cardiovascular issues [46].

Stinging nettle's therapeutic effects extend beyond traditional uses, with scientific studies confirming its antimicrobial, antiviral, antioxidant, anti-inflammatory, anti-ulcer, and anti-hyperlipidemic properties. It has been shown to help regulate blood glucose levels, stimulate insulin secretion, and reduce oxidative stress in diabetic conditions. Preclinical studies have also indicated that nettle can improve the metabolic profile of diabetic animals, influence pancreatic islet structure, and restore glucose metabolism. *Urtica dioica* has a complex relationship with diabetes mellitus, with some studies showing it can act as an alpha-glucosidase inhibitor, reducing postprandial blood glucose levels. However, conflicting results have emerged, with some findings indicating that nettle's effects on blood sugar may not always be significant, and its exact mechanisms of action remain unclear [47].

*Abelmoschus esculentus* L. (okra) has been widely studied for its potential in managing diabetes mellitus. Both its fruits and seeds are known to reduce blood

glucose levels in animal models, attributed mainly to their polyphenolic content. Okra is traditionally used in various regions for its medicinal properties, including its role in managing gastric issues, irritable bowel syndrome, and inflammation, as well as its benefits in stabilizing blood sugar levels. Okra seeds, in particular, are rich in quercetin and other antidiabetic compounds. Studies suggest that okra's antidiabetic effects may involve inhibiting enzymes like  $\alpha$ -amylase and  $\alpha$ -glucosidase, which slow carbohydrate absorption and reduce postprandial blood glucose spikes. However, some research indicates that okra's effects may not always be as potent as conventional drugs like acarbose and metformin. Additionally, okra fruit extracts have demonstrated the ability to improve insulin sensitivity, stimulate insulin secretion, and lower blood glucose levels in diabetic animal models. Okra shows promise as a natural remedy for diabetes mellitus, particularly due to its antioxidant properties and the presence of beneficial phytochemicals [48, 49].

### CONCLUSION

Current treatments for diabetes mellitus vary in effectiveness and safety, particularly in managing long-term complications and inflammation. Herbal remedies are increasingly considered as adjunctive therapies, potentially reducing reliance on pharmaceuticals. They offer a possibly safer option with comparable or better efficacy. Herbal medicines may help regulate blood glucose levels, reduce inflammation, and improve metabolic function, often with fewer side effects. Future research should focus on conducting more trials to confirm the safety and efficacy of herbal treatments for diabetes mellitus and its related complications. Further investigation into specific herbal compounds and isolates could lead to more precise therapeutic options. Additionally, developing natural product formulations that optimize bioavailability and pharmacokinetics will be crucial for enhancing treatment outcomes.

### AUTHOR CONTRIBUTIONS

All authors contributed to the manuscript. Conceptualization by Mammadova A. and Nagiyeva M.; resources, data curation, and writing by all authors; review and editing by Mammadova A. and Kazimzade H. They take full responsibility for the integrity of all aspects of the work.

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### CONFLICT OF INTEREST

The authors declare no conflict of interest.

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