

“HERBAL DRUGS USED IN DIABETES MELLITUS”**A COMPREHENSIVE REVIEW OF DIABETES MELLITUS, HERBAL
DRUGS AND FUTURE PROSPECTS*****Rahul Kumar, Sakshi Saini, Sanjiv Duggal**

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DOI: <https://doi-doi.org/101555/ijarp.4033>**ABSTRACT:**

Diabetes mellitus is one of the significant global metabolic disorders because of its rising prevalence, chronicity and long-term related complications impacting on various organ systems. Despite an extensive selection of synthetic antidiabetic medications on the market, the problem of long-term control of the disease is still problematic due to adverse effects, economic issues, and the fact that single-target drugs are not able to cope with the multifactorial pathophysiology of diabetes. In this regard, herbal drugs have gained increasing interest amongst scientists due to their historical applications in traditional medicines and their ability to alter a number of metabolic pathways at the same time. Many medicinal plants have been documented to have antidiabetic effects in a variety of biological processes such as controlling insulin secretion, enhancing peripheral insulin sensitivity, controlling carbohydrate metabolism, and oxidative stress. The glucose-lowering effect of various bioactive compounds of plants has been proved by experimental and clinical studies. This review critically analyzes herbal drugs in the treatment of diabetes mellitus with the focus on their phytochemical components, suggested mechanisms of action and available experimental and clinical data. The review, based on the combination of traditional and modern scientific discoveries, shows the therapeutic applicability, constraints, and future prospects of herbal drugs as complementary treatment in diabetes management.

1. INTRODUCTION

Diabetes mellitus is a chronic metabolic syndrome that is characterized by persistent high levels of glucose in the blood because of insufficient insulin synthesis, reduced insulin activity, or

both. The condition interferes with normal metabolism of carbohydrates, lipids and proteins and has become one of the most urgent worldwide public health issues. [1] The past few decades have seen a sharp increase in the population of people with diabetes and this is attributed to urbanization, lack of exercise, poor dietary habits, rising obesity rates as well as genetic predisposition. This disease affects third world countries more than any other, as the restricted resources in healthcare facilities and access to long term treatment aggravate the general disease burden.[2]

Chronic hyperglycemia is the key factor that contributes to the appearance of complications caused by diabetes. Chronic exposure to high levels of glucose causes structural and functional damage to the various organs, which causes microvascular complications like diabetic neuropathy, nephropathy, and retinopathy, and macrovascular complications including cardiovascular and cerebrovascular diseases. These complications mean a lot in terms of augmented morbidity and mortality and greatly affect the quality of life of the impacted people. Therefore, long-term glycemic control is necessary not only to manage the symptoms but also to decrease the chances of developing long-term complications.[3]

Traditional medical literature and ethnobotanical studies outline that over a thousand species of plants have been used in the world to control diabetes mellitus. These are plants that are obtained in other regions such as leaves, roots, bark, seeds, fruits and in some cases, the whole plant.[4] They possess a wide range of bioactive phytochemicals including alkaloids, flavonoids, phenolic compounds, terpenoids, saponins, tannins and glycosides.[5] Together, these components have antidiabetic effects of diverse biological mechanisms, such as regulation of insulin secretion, maintenance of pancreatic β -cells integrity, enhancement of insulin sensitivity, carbohydrate metabolism, inhibition of hepatic glucose synthesis, and antioxidant effect.[6]

Recently, there has been a scientific resurgence in research with a considerable amount of experimental and clinical studies on medicinal plants frequently used in the management of diabetes. In- vitro research, animal research, and human trial research evidence has indicated that a number of herbal drugs have a considerable glucose-lowering effect as well as a positive effect on lipid metabolism and parameters of oxidative stress. [7] Due to their comparatively low cost, perceived safety, and capacity to act on various metabolic pathways, herbal drugs are becoming more and more actively considered as either complementary or alternative to long-term diabetes management.[8]

The scientific literature has reported numerous medicinal plants that have well-documented antidiabetic potential and the major bioactive constituents of these plants. Table 1 provides a

consolidated summary of significant antidiabetic herb plants, their botanical families, parts used and major active principles. This summary demonstrates the range of plant materials and phytochemicals as they affect diabetes treatment and gives a paradigm concerning the pharmacological utility of herbal medications that will be explained further^[9]

The current review is intended to synthesize and critically appraise the herbal drugs in diabetes mellitus management paying special attention to the phytochemical components, proposed mechanisms of action, experimental and clinical studies, the benefits, limitations, and future research opportunities. Through the combination of conventional wisdom and contemporary scientific discoveries, this review aims to be a complete guide to students, researchers, and other medical practitioners in the pharmacy and pharmaceutical sciences^[10]

2. Diabetes Mellitus: Overview and Pathophysiology

Diabetes mellitus is a persistent endocrine condition that is characterized by the inability to regulate levels of glucose in the bloodstream. It influences the metabolism of carbohydrates, fat, and proteins and causes both acute and chronic complications.^[11] Diabetes mellitus is categorized as Type 1 diabetes mellitus, Type 2 diabetes mellitus, gestational diabetes mellitus, and other types that are related to genetic defects, pancreatic diseases, endocrinopathies, or drugs.^[12]

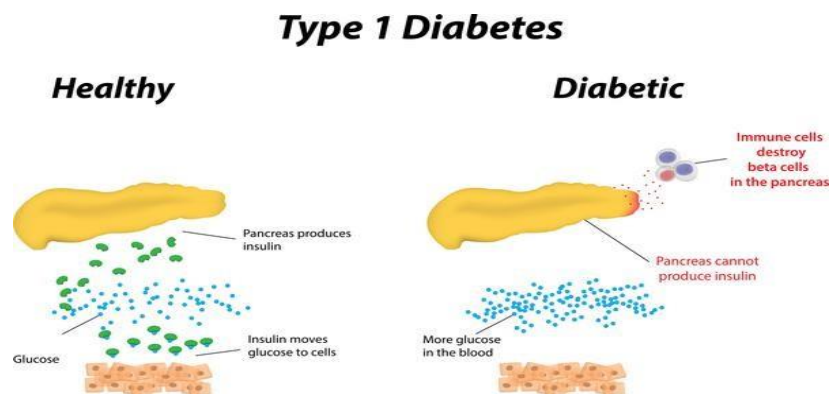


Fig 1: Pathophysiology of diabetes mellitus. ^[13]

Diabetes mellitus type 1 is an autoimmune disease that leads to the destruction of pancreatic β - cells and the following absolute insulin deficiency. The most prevalent type of diabetes mellitus in most countries of the world is type 2 diabetes mellitus, which is marked by insulin resistance coupled with relative insulin deficiency and is closely linked with obesity, sedentary lifestyle, and genetic factors. Gestational diabetes mellitus is a condition that develops in pregnancy and

predisposes the development of Type 2 diabetes in later adulthood.^[14]

Oxidative stress is a major pathogenesis of diabetes and complications. Chronic hyperglycemia causes overproduction of reactive oxygen species, stimulation of the polyol pathway, the production of advanced glycation end products, the activation of protein kinase C, and the upsurge of hexosamine pathway flux. The effects of these processes include the damage of cells, dysfunction of the endothelium, inflammation, as well as insulin signaling.^[15]

2.1 Rationale for Herbal Drugs in Diabetes Management

This has rekindled interest in herbal medicines due to the growing prevalence of diabetes and the shortcomings of artificial antidiabetic medication. Herbal drugs have a number of benefits, such as multitarget mechanisms of action, reduced cost, cultural acceptability, and in general reduced side effects with appropriate use. ^[16] Most of the herbal medicines do not only reduce the level of blood glucose but also treat related metabolic disorders that may include dyslipidemia, oxidative stress, and inflammation.^[17]

Hundreds of plants potentially possessing antidiabetic activity have been identified by traditional medicinal systems. The contemporary scientific studies have confirmed most of these assertions by proving that herbal medicines may be effective in the form of monotherapy in the initial phase of diabetes or as a complementary medication with antidiabetic medications.^[18]

3. Herbal Drugs Used in Diabetes Mellitus

Numerous medicinal plants have been used and researched to manage diabetes mellitus. These herbal medicines have various and supplementary effects, such as the stimulation of insulin secretion, pancreatic β -cell regeneration and protection, insulin sensitivity, decrease of carbohydrate digestion and absorption, hepatic gluconeogenesis, glucose transporter, and oxidative stress and inflammation. Herbal drugs are especially appropriate in a complex metabolic disorder like diabetes mellitus because of the multitarget nature of the drug.^[19]

3.1 *Momordica charantia* (Bitter Gourd)



Fig 2: Bitter Gourd ^[20]

Momordica charantia (family: Cucurbitaceae) is a medicinal plant that has been heavily researched on as a remedy in diabetes mellitus. It is also referred to as bitter gourd or karela and is highly eaten as a vegetable and also as a medicine. The plant has various bioactive compounds such as charantin, polypeptide-p, vicine, cucurbitane type triterpenoids, alkaloid, and flavonoids. ^[21] It has been shown through experimental studies that *Momordica charantia* has a considerable impact on hypoglycemic and antihyperglycemic effects in normal and diabetic animals. Polypeptide-p has an insulin-like effect and charantin increases glucose uptake of the peripheral tissues. The plant also prevents the absorption of glucose in the intestine and enhances the functioning of the β -cells of the pancreas. Clinical trials have found decreases in postprandial and fasting blood glucose levels when bitter gourd preparations are taken. It is also an antioxidant that aids in the alleviation of the oxidative stress, thus, helping in the prevention of diabetic complication. ^[22]

3.2 *Trigonella foenum-graecum* (Fenugreek)

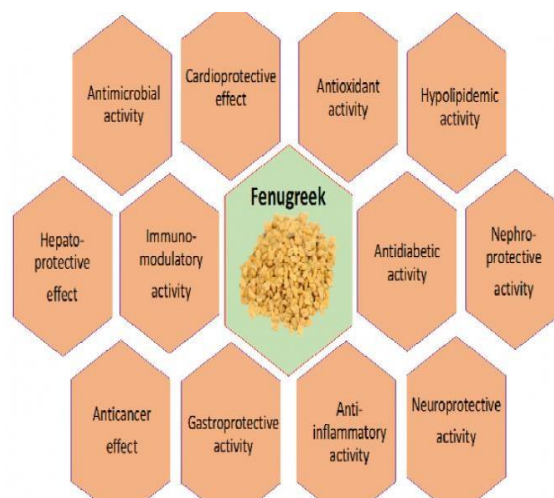


Fig 3: Benefits of fenugreek. ^[23]

Fenugreek (family: Fabaceae) seeds are commonly used as a food supplement and as a traditional medicine to diabetes mellitus. They also include alkaloids, flavonoids, saponins, galactomannan- rich soluble fiber and the amino acid 4- hydroxyisoleucine that has a major role in glucose metabolism. Fenugreek has an antidiabetic mechanism that slows down the gastric emptying process, decreases intestinal glucose absorption, increases insulin secretion, and raises insulin sensitivity.^[24] The large amount of fiber retards the rate of digestion and absorption of carbohydrates, thus minimizing the postprandial hyperglycemia. A number of clinical trials have reported that consumption of fenugreek seed powder or extracts led to a significant reduction in fasting blood glucose levels and an increased glucose tolerance in diabetic patients.^[25]

3.3 Azadirachta indica (Neem)

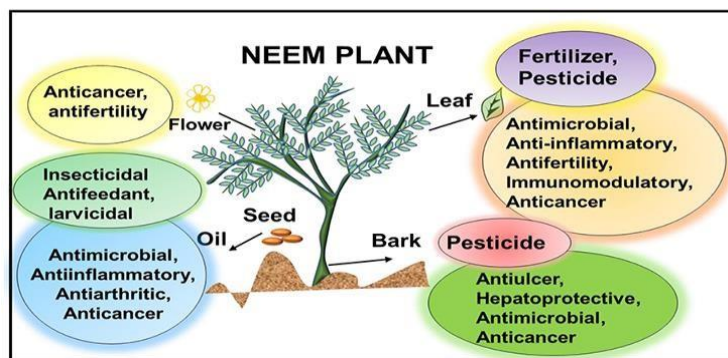


Fig 4: Neem Plant.^[26]

Azadirachta indica (family: Meliaceae), also known as neem, is a popular herb in traditional medicine that is used to treat diabetes and its complications. Nimbin, nimbidin, azadirachtin, flavonoids, and tannins are some of the bioactive compounds found in the leaves.^[27] This plant is also a potent antioxidant and anti-inflammatory compound and prevents the oxidative destruction of pancreatic β -cells. According to experimental literature, neem can be useful in the treatment of lipid abnormalities that are usually linked to diabetes.^[28]

3.4 *Cinnamomum verum* (Cinnamon)



FIG 5: CINNAMON ^[29]

Cinnamomum verum (family: Lauraceae) is a widely used food seasoning spice that has well-known antidiabetic effects. Its bioactive components are cinnamaldehyde, cinnamic acid, polyphenols and procyanidins. Cinnamon increases insulin sensitivity by increasing insulin receptor phosphorylation and glucose uptake in peripheral tissues.^[30] A number of clinical trials have shown decreases in fasting blood glucose, glycated hemoglobin (HbA1c), and serum lipid levels in diabetic patients who are taking cinnamon supplementation. Its antioxidant effect also adds to the enhanced metabolic control.^[31] Cinnamon also offers several additional health benefits beyond basic metabolic support. It may help in weight management by boosting metabolism and reducing appetite. It also has mild pain-relieving properties and can help reduce muscle soreness. Furthermore, cinnamon may enhance skin health due to its antimicrobial and anti-aging effects, making it useful in both dietary and topical applications.^[32]

3.5 *Ocimum sanctum* (Tulsi) *Ocimum sanctum* (family: Lamiaceae), or tulsi or holy basil, is a significant medicinal plant that has antidiabetic, antioxidant, and adaptogenic effects. The leaves have eugenol, flavonoid, phenolic, and essential oils.^[34] Tulsi is reported to lower blood glucose levels during fasting and postprandial period through increased secretion of insulin and also by increasing the metabolism of glucose. It is also effective in enhancing lipid profiles and protection against cellular damage caused by oxidative stress. All these characteristics render tulsi an important adjunct in the management of diabetes.^[35]

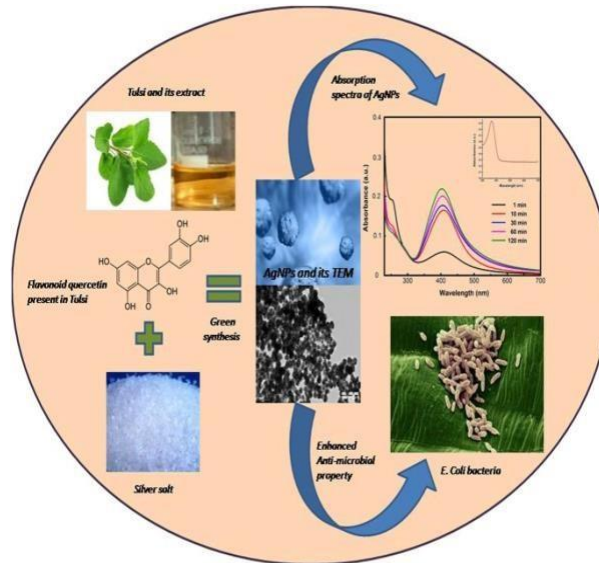


Fig 6: Constituents of tulsi. [33]

4. Phytochemical Constituents Responsible for Antidiabetic Activity

In contrast to most of the current synthetic antidiabetic drugs that influence only one or a few biochemical pathways, herbal drugs tend to have a complex, complementary effect. The bioactive substances, which are of plant origin, can affect the glucose metabolism on different levels such as the pancreatic, hepatic, intestinal and peripheral tissues. Other phytochemicals stimulate the secretion of insulin or maintain the activity of the pancreatic beta-cell, whereas others increase the insulin responsiveness of peripheral tissues like muscle and adipose tissue.[36]

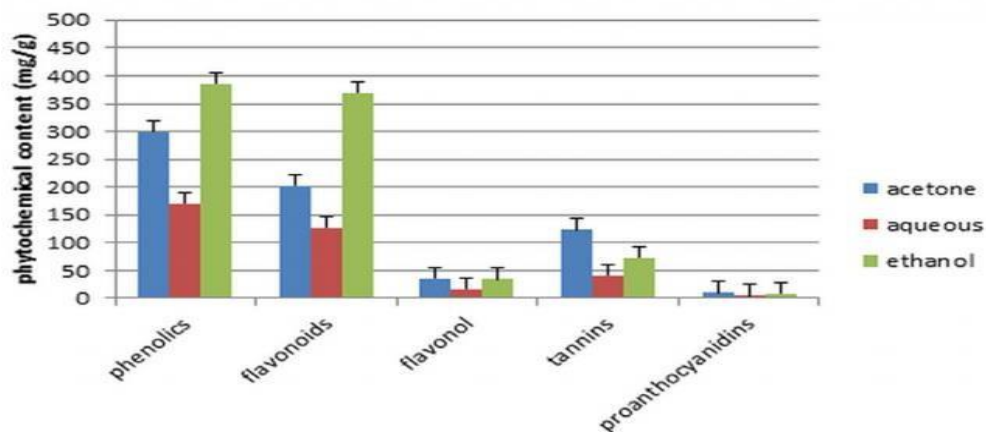


Fig 7: Graph of phytochemical constituents [37]

Moreover, there are other herbal constituents that alter the intestinal glucose processing by slowing down the digestion of carbohydrates or by inhibiting the intestinal glucose absorption, thus, alleviating the postprandial hyperglycemia. The antidiabetic potential of many medicinal plants is also helped by their antioxidant and antiinflammatory effects in the reduction of oxidative stress and inflammatory events involved in diseases and complications.^[38] The possibility of simultaneous effect of herbal drugs upon a number of metabolic targets may be the reason of its perceived positive effects in the overall glycemic control and metabolic balance in diabetes mellitus.^[39]

5. Advantages of Herbal Drugs in Diabetes Management

Herbal drugs have various practical and curative benefits which would make them appealing in the long-term management of diabetes mellitus especially as complimentary therapies. The capacity to have effect on several metabolic pathways at the same time is one of the greatest merits of herbal medicines. Because diabetes mellitus is a multifactorial condition that includes insulin secretion, insulin resistance, oxidative stress, and inflammation, multitarget therapies could have more comprehensive metabolic advantages than single-target synthetic drugs.^[40]

The relatively good safety profile of herbal drugs is another important strength of the latter. Numerous medicinal plants have been eaten or used as a traditional food, or remedy over centuries, and this gives them a historical basis of tolerability. In contrast to a few synthetic antidiabetic compounds linked with undesirable effects like hypoglycemia, nausea, and weight gain, herbal drugs are usually viewed to have fewer and less significant side effects, particularly when they are taken in therapeutic dosages.^[41]

The affordability and ease of access also make herbal medicines widely used especially in developing nations. Herbal solutions are usually locally present, cheap and culturally acceptable and can be used in populations that have low access to modern medical care. Moreover, a number of herbal drugs not only contribute to better glycemic control, but they also have a positive influence on lipid metabolism and oxidative stress, thus, possibly preventing the occurrence of diabetes-associated complications.^[42]

6. Limitations And Safety Concerns

Although these herbal drugs have their possible advantages, there are a number of limitations that are linked to their use in managing diabetes and which should be taken into account. Absence of standardization of herbal formulations is one of the biggest problems. Active phytochemical constituents can be highly concentrated and highly fluctuate with different

factors like plant species, geographical origin, cultivation conditions, harvesting timings and processing. Such inconsistency may result in uneven treatment results.^[43]

The other critical constraint is the lack of well-designed and large-scale clinical trials of most herbal drugs. Although there are several experimental and pre-clinical studies that confirm the antidiabetic properties of medicinal plants, there are often no strong clinical studies that would support the use of medicinal plants in the same way as the conventional drugs. Consequently, it is not always possible to come up with conclusive results on efficacy, optimum dose, and safety in the long run.^[44]

The issues of safety connected to the interactions between herbs and drugs are also worth consideration, especially when the patient has traditional antidiabetic drugs. Some of the herbal drugs can either enhance the efficacy or disrupt the action of the synthetic drugs and thus cause hypoglycemia or lowering therapeutic efficacy. Besides, when appropriate quality control measures are not established, problems related to contamination, adulteration, and misidentification of plant materials can present a serious health hazard.^[45]

7. Future Prospects

The future of research in herbal medicine for diabetes mellitus is centered on making these therapies more reliable, effective, and scientifically accepted. One of the key directions is the isolation and characterization of active compounds from medicinal plants, which helps in identifying the exact constituents responsible for antidiabetic activity. This allows for better understanding of their mechanisms and ensures consistent therapeutic effects.^[46] Another important aspect is the standardization of herbal preparations, as variability in plant sources, extraction methods, and formulation can lead to inconsistent results. Establishing uniform quality control measures will improve safety and reproducibility. Additionally, well-designed clinical trials involving larger populations are essential to validate the efficacy and safety of these herbal drugs under controlled conditions.^[47] Furthermore, combining herbal medicines with conventional antidiabetic therapies offers a promising strategy, as it may enhance treatment outcomes while minimizing side effects. Such integrative approaches could lead to the development of safer, more effective, and patient-friendly diabetes management options.^[48]

8. CONCLUSION

Herbal medications represent a promising and increasingly important approach in the management of diabetes mellitus, particularly due to their long history of traditional use and relatively favorable safety profiles. Numerous medicinal plants have demonstrated significant

antidiabetic activity through diverse mechanisms, such as enhancing insulin secretion, improving insulin sensitivity, reducing intestinal glucose absorption, and exhibiting antioxidant properties that help mitigate oxidative stress associated with chronic hyperglycemia. Commonly studied herbs like bitter melon, fenugreek, and gymnema have shown potential in regulating blood glucose levels and supporting metabolic balance. However, despite these encouraging findings, herbal medicines cannot completely replace conventional antidiabetic therapies, especially in moderate to severe cases where precise glycemic control is critical. Instead, they are best utilized as complementary agents alongside standard pharmacological treatments, potentially improving therapeutic outcomes and reducing side effects when used appropriately. For herbal medicines to be effectively integrated into modern healthcare systems, there is a strong need for rigorous scientific validation through clinical trials, standardization of active constituents, and quality control in manufacturing processes. Additionally, proper regulatory oversight is essential to ensure safety, efficacy, and consistency. With these measures in place, herbal therapies could play a valuable supportive role in holistic diabetes management, bridging traditional knowledge with evidence-based medicine.

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