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A REVIEW ON ANTI-DIABETIC OF HERBS

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Abstract

One of the most prevalent metabolic diseases, diabetes mellitus affects 2.8% of people worldwide and is expected to rise to 5.4% by 2025. Herbal remedies have long been regarded as a very reputable form of treatment, and as a result, they are increasingly being used in high-tech, contemporary medicinprofiles of 65 species of plants with hypoglycemic qualities that can be found in literature sources from different databases. These profiles are appropriately categorized based on the parts that are used, the way that blood glucose is reduced, and active phytoconstituents that have insulin-mimetic activity. Plants with hypoglycemic potential are primarily found in the Leguminoseae, Lamiaceae, Liliaceae, Cucurbitaceae, Asteraceae, Moraceae, Rosaceae, and Araliaceae families, according to the review. the plants that are most active. One of the most prevalent metabolic diseases, diabetes mellitus affects 2.8% of people worldwide and is expected to rise to 5.4% by 2025. Herbal remedies have long been regarded as a very reputable form of treatment, and as a result, they are increasingly being used in high-tech, contemporary medicine. Given the aforementioned considerations, the current review offers profiles of 65 species of plants with hypoglycemic qualities that can be found in literature sources from different databases. These profiles are appropriately categorized based on the parts that are used, the way that blood glucose is reduced, and active phytoconstituents that have insulin-mimetic activities. Given the aforementioned considerations, the current review offers

***Keywords*:** Diabetes mellitus; Metabolic disease; Herbal medicine; Hypoglycemic plants; Antidiabetic activity.

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Introduction

Insufficient insulin secretion or activity is a hallmark of diabetes mellitus, a chronic metabolic disorder. Protein, carbohydrate, and fat metabolism can all go haywire when the anabolic hormone insulin is absent [1]. These metabolic disorders are caused by low insulin levels, insulin resistance of target tissues, abnormalities in skeletal muscles and adipose tissue, and to a lesser extent in the liver, signal transduction system, effector enzymes or genes, and/or signal transduction pathway. Diabetes, one of the most common metabolic diseases in the world, now affects 2.8% of the global population and is predicted to rise to 4.4% by 2030, an unprecedented epidemic level. Despite not being a communicable disease, diabetes is considered to be among the top five worldwide morbidities. The type and frequency of diabetes are determined by the intensity of the symptoms. Some diabetics, particularly those with type 2 diabetes, show no symptoms at all in the early stages of the disease, while others display clear signs of hyperglycemia [1, 2].

1. Overview of Diabetes Mellitus

Diabetes mellitus (DM), a chronic metabolic condition brought on by defects in either insulin secretion, insulin action, or both, is characterized by hyperglycemia, or increased blood glucose. The hormone insulin, which helps the body use glucose as fuel, is produced by the pancreatic β-cells. When insulin synthesis or function is impaired, glucose accumulates in the bloodstream instead of being used by the cells [3].

2 Global Prevalence and Health Impact

One of the diseases that are spreading the fastest in the world is diabetes mellitus (DM). An estimated 537 million individuals between the ages of 20 and 79 will have diabetes in 2021, 643 million by 2030, and 783 million by 2045, according to the International Diabetes Federation

(IDF). Low- and middle-income nations have seen the largest increases, mostly as a result of rising urbanization, unhealthy eating habits, obesity, and a decline in physical activity. One of the main causes of early death and disability is diabetes mellitus. Every year, it directly causes more than 6.7 million deaths worldwide. Serious consequences, including stroke, heart disease, renal failure, and blindness.

3. Limitations of Conventional Antidiabetic Therapy

Conventional antidiabetic treatments, including insulin and oral hypoglycemic agents such as sulfonylureas, biguanides (metformin), thiazolidinediones, and DPP-4 inhibitors, are effective in controlling blood glucose levels but have several limitations and side effects. Long-term use of these drugs may lead to drug resistance, hypoglycemia, weight gain, and gastrointestinal disturbances .Many patients find it difficult to maintain blood sugar within the normal range due to poor adherence, cost of treatment, and the need for lifelong therapy. Additionally, conventional drugs usually target a single mechanism of action, while diabetes is a multifactorial disease involving insulin resistance, oxidative stress, and β-cell dysfunction. Because of these limitations, there is growing interest in herbal and natural remedies that act on multiple targets, are more affordable, and have fewer side effects [4. 5].

4. Importances of Herbal Medicines In Diabetics Management

Particularly in underdeveloped nations where contemporary medications are frequently more expensive or harder to obtain, herbal medicine is crucial in the treatment of diabetes mellitus. Strong antidiabetic effects have been demonstrated in both laboratory and clinical investigations for a number of plants utilized in traditional medical systems, including Ayurveda, Unani, and Traditional Chinese Medicine. Because they are natural, reasonably priced, and typically have less adverse effects than synthetic medications, herbal remedies are becoming more and more popular. Frequently, they affect several biological targets, including promoting insulin production, enhancing insulin sensitivity, decreasing intestinal absorption of glucose, and shielding pancreatic β-cells from oxidative damage (figure 01). [6].

Figure 01: Overview of Diabetes Mellitus, Global Prevalance, Important Of Herbal Medicine in Diabetes Management.

Classification of Diabetics Mellitus

Diabetes mellitus (DM) is classified into several types based on the cause and mechanism of disease.

1. Type 1 Diabetes Mellitus (Insulin-Dependent)

Also called insulin-dependent diabetes mellitus, Caused by auto-immune destruction of pancreatic β-cells, little or no insulin production. Usually occurs in children and young adults. Patients require daily insulin injections for survive [7].

2. Type 2 Diabetes Mellitus (Non-Insulin-Dependent)

The prevalent type of diabetes, accounting for 90–95% of all cases. Occurs when the pancreas produces insufficient amounts of insulin or when the body develops resistance to it. linked to bad diet, obesity, and a sedentary lifestyle Changes in lifestyle, oral hypoglycemic medications, and occasionally insulin are used to address this condition (figure 02). [8].

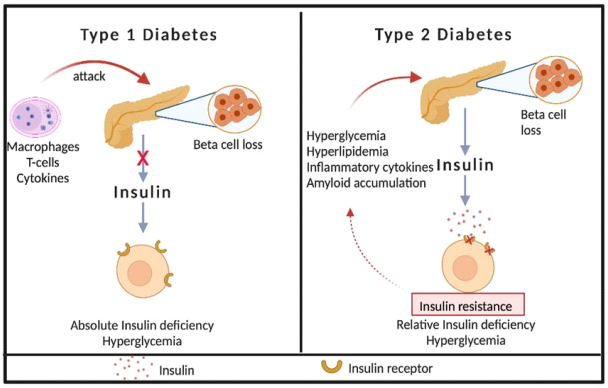

Figure 02: Type-1 Diabetes Mellitus and Type-2 Diabetes Mellitus

3. Gestational Diabetes Mellitus

The type of diabetes known as gestational diabetes mellitus (GDM) typically manifests in the second or third trimester of pregnancy. It happens when pregnancy-related hormonal changes result in insulin resistance, which reduces the body's ability to use insulin to lower blood sugar. Blood glucose levels rise over normal as a result. GDM usually goes away after giving delivery, but if left untreated, it might have major consequences. Premature delivery, low blood sugar in the newborn, huge birth weight (macrosomia), and birth problems can all result from high blood sugar during pregnancy. In addition, women with GDM are more likely to get Type 2 diabetes in the future.

4. Secondary Diabetes Mellitus

Instead of being caused by a direct flaw in the manufacture or usage of insulin, secondary diabetes mellitus is a form of the disease that arises as a result of another illness or drug. It happens when the pancreas is harmed by certain illnesses or outside variables that alter insulin secretion or heighten insulin resistance [10].

5. Common Causes Include

Pancreatic diseases such as chronic pancreatitis, pancreatic cancer, or surgery on the pancreas.

Hormonal disorders like Cushing's syndrome, acromegaly, or pheochromocytoma, which raise blood glucose levels by increasing insulin resistance. Genetic defects in insulin action or pancreatic β-cell function. Drug-induced diabetes, caused by long-term use of medicines such as glucocorticoids (steroids), thiazide diuretics, oral contraceptives, or antipsychotic drugs.

Role of Herbal Medicine in Diabetes

1. Historical Use of Plants in Traditional Systems (Ayurveda, Chinese, Unani, Etc.)

People have been using medicinal herbs to treat diabetes and other ailments for thousands of years. Traditional medicinal systems including Ayurveda (India), Traditional Chinese Medicine (TCM), and Unani have made substantial use of herbs to improve overall health and regulate blood sugar. In Ayurveda, diabetes is called "Madhumeha," or "honey urine disease." Ancient Ayurvedic texts like the Charaka Samhita and Sushruta Samhita list over 20 herbs that have antidiabetic properties. These consist of Gymnema sylvestre (gurmar), Momordica charantia (bitter gourd), and Trigonella foenum-graecum (fenugreek). In Traditional Chinese Medicine (TCM), diabetes is referred to as "Xiaoke" (wasting-thirst sickness). Herbs including Panax ginseng, Astragalus membranaceus, and Coptis chinensis have been used to increase energy (Qi) and regulate blood sugar. In addition to recognizing diabetes (known as Ziabetus), the Unani system, which has its roots in Greek and Arab medicine, recommended medicines such Syzygium cumini (Jamun) and Cinnamomum zeylanicum (Cinnamon) to reduce excessive thirst and urination.Many of these ancient systems' medicines have been scientifically shown to have antidiabetic benefits, and they served as a basis for contemporary herbal research [11, 12].

2. Advantages of herbal drugs (low toxicity, cost-effectiveness, multiple mechanisms)

Low Side Effects: Most herbs are natural and safer than synthetic drugs, which can cause low blood sugar or weight gain.

Affordable: Herbal remedies are cheaper and easy to find. Multiple Ways to Work: Herbs can help the pancreas make insulin, improve insulin use, slow sugar absorption, and protect body cells.

Extra Health Benefits: Many herbs also act as antioxidants, reduce inflammation, and improve cholesterol [13].

3. WHO Recommendations for Traditional Medicine

The World Health Organization (WHO) recognizes the important role of traditional and herbal medicine in healthcare, including for diabetes management. WHO encourages:

Scientific Evaluation: Traditional remedies should be tested for safety, effectiveness, and quality before use.

Integration with Modern Medicine: Safe and effective herbal medicines can be used alongside modern treatments to improve health outcomes.

Standardization and Quality Control: Herbal products should have consistent quality, correct dosage, and proper labelling.

Education and Research: WHO recommends training healthcare professionals about traditional medicine and supporting research on medicinal plants [14, 15].

Mechanism of Anti-Diabetic Action of Herbs

1. Stimulation of insulin secretion (β-cell regeneration)

Certain herbs stimulate the β-cells, the cells that make insulin, causing the pancreas to create more of it. They might also assist the body naturally control blood sugar by repairing damaged β-cells.

Examples of herbs that do this:

The bitter gourd, Mordica charantia, has substances that increase the release of insulin by mimicking it. anti-inflammatory and antioxidant properties.Fenugreek, or Trigonella foenum-graecum, enhances glucose tolerance and insulin secretion. Because β-cell destruction frequently lowers insulin production in Type 1 and severe Type 2 diabetes, this function is crucial. Blood sugar regulation can be naturally enhanced by herbs that promote β-cell renewal [16, 17].

2. Enhancement of insulin sensitivity

Enhancing insulin sensitivity is the term used to describe how certain herbs help the body use insulin more efficiently. This indicates that insulin has a greater effect on the cells in the muscles, fat, and liver, enabling glucose to enter the cells and reducing blood sugar levels. Herbs that improve insulin sensitivity, for instance:

Cinnamon (Cinnamomum zeylanicum): Improves insulin receptor activity and glucose uptake by cells.

Aloe vera: Reduces insulin resistance and improves blood sugar control. This mechanism is especially important in Type 2 diabetes, where the body often produces enough insulin but the cells don't respond properly. Herbs that improve insulin sensitivity can help control blood sugar naturally without causing hypoglycaemia [18,19].

3. Inhibition of carbohydrate-digesting enzymes (α-amylase, α-glucosidase)

Some herbs help lower blood sugar after meals by slowing down the digestion of carbohydrates. They inhibit enzymes like α-amylase (breaks down starch) and α-glucosidase (breaks down sugars), which delays glucose absorption in the intestines.

Examples of Herbs That Work This Way

Bitter gourd (Momordica charantia): Reduces the breakdown of starch into sugar.

Fenugreek (Trigonella foenum-graecum): Slows carbohydrate absorption and improves post-meal blood sugar. For people with Type 2 diabetes, where regulating postprandial (after meal) blood sugar rises is crucial, this method is extremely beneficial. These herbs aid in

preventing abrupt increases in blood glucose by delaying the absorption of sugar [20, 21].

4 Antioxidant and anti-inflammatory effects

Numerous herbs aid in the management of diabetes by lowering inflammation and oxidative stress, two main factors that contribute to β-cell destruction and insulin resistance.While anti-inflammatory substances lessen inflammation in organs like the muscles, liver, and pancreas, antioxidants in plants counteract dangerous free radicals.

Examples of herbs with these effects:

Tulsi (Ocimum sanctum): Reduces inflammation and protects β-cells.

Garlic (Allium sativum): Has antioxidant properties that lower blood sugar and improve insulin function.

Aloe Vera: Protects cells from oxidative damage and reduces insulin resistance.

Cinnamon (Cinnamomum zeylanicum): Combats oxidative stress and inflammation, improving glucose metabolism (Figure 03) [22, 23].

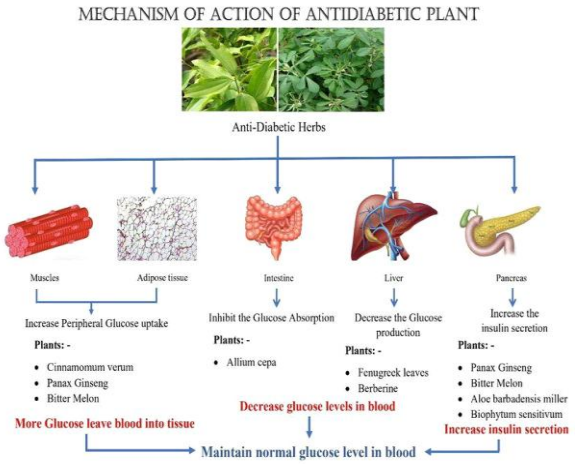

Figure 03: Mechanism of Action of Anti-Diabetic Plant

5 Modulation of glucose uptake and lipid metabolism

Certain herbs assist control diabetes by balancing fat metabolism and enhancing the body's utilization of glucose. This implies that they improve overall blood sugar regulation by assisting muscle and fat cells in absorbing more glucose from the circulation and preventing fat buildup.

Examples of herbs that work this way

Fenugreek (Trigonella foenum-graecum): Increases glucose uptake in muscles and reduces cholesterol and triglycerides.

Bitter gourd (Momordica charantia): Helps cells use glucose more efficiently and lower fat in the liver.

Cinnamon (Cinnamomum zeylanicum): Improves glucose transport into cells and regulates lipid metabolism. By improving glucose uptake and fat metabolism, these herbs help control blood sugar, reduce insulin resistance, and prevent diabetes-related complication [24].

Important Anti-Diabetic Herbs

Table 01: Important Anti diabetic Herbs

Tulsi (Holy basil)	*Ocimum sanctum*	Improves insulin function, antioxidant
Aloe vera	*Aloe barbadensis*	Helps control sugar and fat levels
Cinnamon	*Cinnamomum zeylanicum*	Improves insulin activity
Garlic	*Allium sativum*	Lowers glucose and cholesterol
Ginseng	*Panax ginseng*	Helps in insulin secretion and action
Trigonella foenum-graecum (Fenugreek)	*4-Hydroxyisoleucine, Trigonelline*	Improves glucose tolerance [25,26].

Comparison between Herbal and Synthetic Drugs

Table 02: Comparison between Herbal and Synthetic Antidiabetic Drugs

Parameter	Herbal Drugs	Synthetic Drugs
Source	Natural (plants, extracts)	Chemical or synthetic origin
Mechanism of Action	Multiple (insulin secretion, enzyme inhibition, antioxidant effects)	Usually single target (e.g., increase insulin or reduce glucose production)
Onset of Action	Slow but long-term	Fast and effective
Side Effects	Mild or fewer (if used correctly)	Can cause hypoglycemia, weight gain, or GI upset
Cost	Generally low and affordable	Often expensive
Availability	Easily available, especially in rural areas	Limited in some areas; prescription needed
Standardization	May vary depending on preparation	Fixed and well-standardized doses
Long-Term Safety	Considered safe with traditional use	Known risks after long use (e.g., drug resistance, side effects)27,28

Advantages and Limitations of Herbal Antidiabetics

Advantages

- Natural origin and minimal side effects
- Multiple targets for glycemic control
- Cost-effective and culturally accepted

Limitations

- Lack of standardization and dosage guidelines
- Variability in active constituents
- Limited large-scale clinical data [29, 30].

Recent Advances in Herbal Anti-Diabetic Research

1. Nanoformulations of Herbal Extracts

Nanoformulations are minuscule (nano-sized) carriers that contain plant chemicals or herbal extracts. Herbs become more stable and easier for the body to absorb when they are turned into nanoparticles.

Common types

Nanoemulsions — oil + water droplets that carry plant oils/compounds.

Solid lipid nanoparticles (SLN) — tiny fat particles that trap herbal actives.

Polymeric nanoparticles — natural/synthetic polymers (e.g., chitosan) carrying the extract.

Liposomes / Niosomes — small lipid vesicles that deliver herbal molecules to cells.

Metallic (green-synthesized) nanoparticles — plant extracts used to make silver/gold/zinc nanoparticles with bioactivity [31, 32].

2. Synergistic Polyherbal Formulations

Polyherbal formulations are mixtures of two or more medicinal plants that work together to give better therapeutic effects than single herbs alone. This idea comes from Ayurveda and traditional medicine, where herbs are combined to balance actions and reduce side effects.

Table 03: Synergistic Polyherbal formualtions

Formulation/ Combination	Common Herbs Used	Reported Action
Triphala	Emblica officinalis, Terminalia chebula, Terminalia bellirica	Improves glucose tolerance and antioxidant defense
Diarex (Himalaya)	Gymnema sylvestre, Momordica charantia, Eugenia jambolana	Reduces blood glucose, enhances insulin action
Diabecon (Himalaya)	Gymnema sylvestre, Pterocarpus marsupium, Tinospora cordifolia	Lowers fasting glucose and HbA1c in mild diabetes
Ayush-82	Momordica charantia, Tinospora cordifolia, Trigonella foenum-graecum	Used clinically for type 2 diabetes; improves lipid profile.33

3. Molecular docking and bioinformatics approaches

Molecular docking is a computer simulation that predicts how a small molecule (like a compound from a herb) fits into a target protein's active site-like a key fitting into a lock.

Purpose in Antidiabetic Research

Helps identify potential active compounds from herbs.

Predicts binding strength and stability between compound and enzyme.

Reduces the need for expensive lab testing.

Bioinformatics Tools and Approaches

Bioinformatics combines biology, chemistry, and computer science to analyze data about herbal compounds and their targets.

Applications

Database Mining: To find bioactive plant molecules (e.g., IMPPAT, TCMSP).

Network Pharmacology: To understand how one herb acts on multiple targets (multi-target therapy).

ADMET Analysis: Predicts Absorption, Distribution, Metabolism, Excretion, and Toxicity of herbal compounds [34,35].

4. Standardization and Quality Control Methods

Assuring that each batch of herbal medicine has the same level of quality, purity, and potency is known as standardization. Like synthetic pharmaceuticals, it helps ensure that the product is consistent, safe, and effective.

Quality control ensures that every herbal product meets set standards before reaching consumers.

Main Tests Include

Organoleptic Evaluation: Colour, smell, taste, and texture.

Chemical Analysis: To confirm presence and concentration of active components.

Microbiological Testing: Ensures product is free from harmful microbes.

Toxicity Testing: To check for safety in animals or cell cultures [36, 37].

Future Perspectives

1. Standardization and quality control to ensure consistent potency and purity.
2. Advanced formulations (like nanoformulations) to improve bioavailability and targeted delivery.
3. Bioinformatics and molecular studies to identify active compounds and clarify mechanisms of action.
4. Regulatory frameworks and awareness to support safe, evidence-based use globally [38, 39].

Conclusion

Herbal medicines can help manage diabetes safely and effectively. They work in many ways: increase insulin, help cells use sugar, slow sugar absorption, and reduce inflammation and oxidative stress. Traditional herbs like *Gymnema sylvestre*, *Momordica charantia*, *Fenugreek*, and *Tinospora cordifolia* have been used for a long time and modern studies support their benefits.

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All authors are contributed equally.

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