

# Phytomedicine in the Treatment of Diabetes Mellitus: An Evidence Based Review

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**Abstract**—Diabetes mellitus (DM) is a chronic metabolic disorder characterized by impaired insulin secretion, insulin resistance, or both, leading to elevated blood glucose levels. It has turned into a worldwide health emergency that calls for efficient management techniques. Many cultures have long used phytomedicines, or plant-based pharmaceuticals, to treat diabetes. The purpose of this evidence-based review is to evaluate the clinical data, mechanisms of action, and efficacy of using phytomedicines to treat diabetes.

Diabetes mellitus (DM) is an increasing global public health issue with high morbidity and mortality rates. Conventional pharmaceutical methods of management have limiting factors, including side effects and long-term adverse complications. Therefore, there has been an increased interest in phytomedicine, the use of plant-derived products, as an alternative or complementary approach to managing diabetes. This paper aims to provide a thorough review of the current literature on the role of phytomedicine in the management of DM. Randomized controlled trials, preclinical studies, and clinical experience are reviewed, and mechanisms of actions such as antioxidant actions, modulation of glucose metabolism, and anti-inflammatory effects are discussed.

## I. INTRODUCTION

Diabetes is a really common and tough health problem around the world. It's when blood sugar stays too high because the body doesn't make enough insulin or can't use it right. This can cause big problems with your eyes, kidneys, nerves, and heart, and it costs a lot to treat. Even though there are medicines like insulin and other drugs, managing diabetes can still be tricky. These medicines can have side effects, be expensive, and hard to get in some places. Because of this, people are looking more at using plants to help prevent and treat diabetes.

Using plants as medicine has been around for ages in old medical practices like Ayurveda and Chinese Medicine. Lots of plants have been talked about as being good for diabetes. Now, science is backing up some of these claims, finding that many plants have stuff in them like flavonoids and alkaloids that can lower blood sugar. These things might help the body make more insulin, use insulin better, slow down how the body absorbs sugar, and protect the pancreas from harm. Some plants that have been studied a lot for diabetes include bitter melon, gymnemasyvestre, fenugreek, garlic, cinnamon, and jamun. Things found in these plants, like charantin and gymnemic acids, seem to help lower blood sugar in tests. Plus, plant medicines can also give you extra perks like helping with antioxidants, fighting swelling, and lowering bad fats in your blood, which can help keep your body balanced and stop diabetes problems.

More and more, people want to use natural treatments that are backed by proof, which is why plant medicine is getting attention. Still, we have to figure out how to make sure these plant medicines are consistent, good quality, and safe to use with other drugs. To use plant medicine the best way for diabetes, we need strong science, testing on people, and rules to keep things safe.

## II. MECHANISMS OF ACTION OF PHYTOMEDICINES

Phytomedicines display their antidiabetic properties through several mechanisms:

1. **Insulin Sensitization:** Some plants potentiate insulin sensitivity, facilitating glucose uptake by peripheral tissues.

2. Inhibition of Carbohydrate Digestion and Absorption: Some herbs inhibit the rate of carbohydrate digestion thereby preventing carbohydrate-induced postprandial blood glucose elevations.

3. Beta-cell Regeneration and Insulin Secretion: Some phytoconstituents stimulate regeneration of beta-cells in the pancreas and stimulate insulin secretion.

4. Antioxidant and anti-inflammatory effects: Chronic inflammation and oxidative stress are important for the pathogenesis of diabetes. Many plants have antioxidant and anti-inflammatory properties that may protect pancreatic beta cells.

5. Antihyperglycemic effects: Many herbs reduce blood glucose levels by promoting glucose use and/or by inhibiting gluconeogenesis in the liver.

Herbal medicines help with diabetes in a few ways, working on different processes in the body. Lots of active stuff from plants can help the pancreas make more insulin or even help it repair itself, so the body has more insulin to use. Others make the body more sensitive to insulin in places like muscles and fat by increasing glucose transporter expression and improving receptor signaling. Some plant chemicals slow down how the body digests carbs by blocking certain enzymes in the gut. This means less sugar gets absorbed after eating. And some stuff can affect liver enzymes that control how much sugar the liver makes and releases.

Oxidative stress and inflammation are big problems with diabetes because they mess with insulin production. Plant compounds can help fight oxidation and calm down inflammation by neutralizing reactive oxygen species and boosting antioxidant enzyme activity. Herbal medicines can also change how the body handles fat, lowering cholesterol and triglycerides in the blood. Some herbs even trigger incretin hormones or change the gut bacteria, which assists in keeping blood sugar balanced.

Evidence for a Few Common Phytomedicines for Managing Diabetes:

1. Cinnamon (*Cinnamomum verum*)

1. Botanical Description:-

- Family: Lauraceae
- Genus: *Cinnamomum*

- Species: *Cinnamomum verum*
- Common Names : Cinnamomum, Ceylon cinnamon, true cinnamon, sweet cinnamon

*Cinnamomum verum* is indigenous to Sri Lanka and southern parts of India, but it is now grown in various tropical areas. The tree's attractive light-brown bark is smooth and curls into quills when wrapped. The fragrance is sweet and spicy, while the taste is subtler and mild compared to cassia cinnamon (*Cinnamomum cassia*), which is predominantly used around the globe.

2. Phytochemical Composition:-

- Cinnamaldehyde
- Eugenol
- Coumarin
- Flavonoids

Mechanism of action: Increases insulin sensitivity, regulates glucose metabolism.

Evidence: Research has demonstrated that cinnamon supplementation decreases fasting blood glucose levels and hemoglobin A1c levels in subjects with T2DM. A meta-analysis that evaluated 10 studies concluded that cinnamon supplementation significantly decreased fasting blood glucose levels by about 24 mg/dL.

Clinical use: Cinnamon is commonly used at doses of 1–6 grams per day.

Conclusion:-

Cinnamon (*Cinnamomum verum*) is a potential natural treatment for diabetes mellitus, specifically type 2 diabetes. The evidence for its ability to increase insulin sensitivity, improve blood glucose levels, and provide antioxidant and anti-inflammatory properties is appealing as additional treatment options outside of traditional diabetic therapy. The literature supports the physiologic benefits, but there is a need for more studies to establish cinnamon doses, long-term use, and other drug interactions with cinnamon and diabetes treatment. As a general safety precaution, it is recommended that patients work with their healthcare provider before using cinnamon as a part of their diabetes treatment regimen.

2. Bitter Melon (*Momordica charantia*)

Common name:- Bitter Guard, Karela, Balsam Pear, Ampalaya.

Scientific name:-*MomrdicaCharantia*.

Family:- Cucurbitaceae .

Chemical constituents:-Triterpenoids, Polypeptides, Glycosides, Saponins, Alkaloids, Phenol, etc.

Mechanism:- Mimics insulin and stimulates glucose uptake.

Evidence: Clinical trials have established that bitter melon can lower blood glucose levels significantly for animals and humans both. A study found extracts of bitter melon can reduce both blood glucose and HbA1c levels in individuals with T2DM.

Clinical Use: 500–1,000 mg of dried powder or 25–50 mL of fresh juice, taken daily.

### 3. Ginseng (*Panax ginseng*)

Common names:- Asian ginseng, Korean ginseng, Chinese ginseng, true ginseng

Scientific name:-*Panax ginseng*

Family:-Araliaceae

Chemical Constituents:-Polysaccharides, Ginsenosides, Peptides & Proteins.

Mechanism: Improve insulin sensitivity and increasing glucose utilization.

Evidence: A number of studies have demonstrated that ginseng improves insulin sensitivity and lowers blood glucose. In a systematic review, ginseng supplementation resulted in significant reductions in fasting glucose and HbA1c levels in patients with T2DM.

Clinical Use: 200-400 mg of standardised ginseng extract in one day.

Scientific Evidence:-Cognitive function: Clinical studies indicate memory, focus, and reaction time improvements.

Fatigue reduction: Adaptogenic effects reduced stress and exercise-induced fatigue.

Glucose metabolism: Some studies showed minor improvements in insulin sensitivity in type 2 diabetes.

### 4. Berberine (*Berberis* species)

Chemical class:Isoquinoline alkaloid (protoberberine type).

Molecular formula:  $C_{20}H_{18}NO_4^+$

Molecular weight: 336.36 g/mol

Chemical structure: Contains a quaternary ammonium group with a planar aromatic ring system.

Major natural sources:

*Berberis aristata* (Indian barberry)

*Berberis vulgaris* (European barberry)

*Coptis chinensis* (Chinese goldthread)

Berberine has a bunch of medicinal benefits:

- It can help with diabetes by improving how your body handles sugar and insulin.
- It can lower unhealthy cholesterol and fats in your blood.
- It fights off bacteria, fungi, viruses, and protozoa.
- It reduces swelling and protects against cell damage.
- It helps your heart by making it stronger and improving blood vessel function.
- It safeguards your liver from harmful stuff and helps it process fats better.

Mechanism: Improves insulin sensitivity by inhibiting gluconeogenesis.

Evidence: Berberine has been shown to be as effective as metformin for lowering blood glucose levels. In one clinical trial, berberine supplementation resulted in a 20–30% reduction in HbA1c levels and fasting blood glucose levels.

Clinical Use: 500 mg (2-3 times/day).

### 5. Turmeric (*Curcuma longa*)

• Scientific name:*Curcuma longa* L.

• Family:Zingiberaceae

• Common names: Turmeric, Haldi, Haridra, Indian Saffron

• Plant part used: Rhizome (underground stem)

• Major constituents:

- Curcuminoids: Curcumin (diferuloylmethane), Demethoxycurcumin, Bisdemethoxycurcumin
- Volatile oils:  $\alpha$ - and  $\beta$ -turmerone, ar-turmerone, zingiberene, atlantone
- Other compounds: Proteins, carbohydrates, and resins

Chemical formula of curcumin:  $C_{21}H_{20}O_6$

Molecular weight: 368.38 g/mol

What Turmeric Does

- Turmeric, with curcumin as its main ingredient, does a lot of good things for your body:
- Antioxidant – Fights harmful stuff, like reactive oxygen and nitrogen. It also makes your body's antioxidant helpers (SOD, CAT, GPx) work better.

- Anti-inflammatory – It calms things down by blocking NF-κB and COX-2, which are pathways that cause swelling and pain.
- Antidiabetic – It makes your body better at using insulin, lowers blood sugar, and helps control fats in your blood.
- Antimicrobial – It fights off bacteria, fungus, and viruses.
- Hepatoprotective – It keeps your liver safe from damage caused by poisons and stress.
- Cardioprotective – It brings down bad cholesterol (LDL), makes your blood vessels work better, and stops blood clots.
- Anticancer – It stops cancer cells from growing and causes them to die off in test tubes.
- Neuroprotective – It protects your brain cells from stress and plaque.

Mechanism: Anti-inflammatory, antioxidant properties, improves insulin sensitivity.

Evidence: Curcumin has strongly anti-inflammatory properties, which may help to improve insulin resistance. Studies demonstrate that curcumin intake significantly lowers blood glucose levels and improves insulin sensitivity.

Clinical Use: 500–1,000 mg of curcumin extract per day.

#### 6. Fenugreek (*Trigonella foenum-graecum*)

Scientific name: *Trigonella foenum-graecum* L.

Family: Fabaceae

Common names: Fenugreek, Methi, Greek Clover

Plant part used: Seeds and leaves

Constituents:-

Alkaloids: Trigonelline, Gentianine, Carpaine

Steroidal saponins: Diosgenin, Yamogenin, Tigogenin, Neotigogenin

Amino acids: 4-Hydroxyisoleucine (unique insulinotropic amino acid)

Flavonoids and Polyphenols: Vitexin, Isovitexin, Orientin, Quercetin

Fibers and Mucilage: Soluble fibers (galactomannans) that slow glucose absorption

How Fenugreek Works in Your Body ?

Studies suggest fenugreek can do a lot of things:

- For Diabetes: It can bring down blood sugar, help your body make insulin, and improve how your body handles sugar.

- For Cholesterol: It can lower bad fats in your blood.
- As an Antioxidant: It fights damage from harmful molecules in the body.
- For Inflammation: It can reduce inflammatory stuff in your body.
- For Appetite: It can help you feel full and control your appetite.
- For Digestion: It can prevent ulcers and help with digestion.
- For Reproductive Issues: It can help women produce milk and improve testosterone in men.
- For Liver Protection: It can protect your liver from damage.

Mechanism of action: Reduces insulin resistance, slows absorption of carbohydrate.

Evidence base : There are several studies indicating that fenugreek seed consumption improves postprandial glucose and insulin resistance, and one study has indicated that it significantly reduced fasting blood glucose and HbA1c in patients with T2DM.

Clinical recommendations: Ground seeds 5–10 grams per day.

#### 7. Aloe Vera (*Aloe barbadensis miller*)

Scientific name: *Aloe barbadensis* Miller

Family: Asphodelaceae (formerly Liliaceae)

Common names: Aloe vera, Ghritkumari (Hindi), Kumari (Sanskrit), Burn plant

Habitat: Native to North Africa and the Arabian Peninsula; widely cultivated in tropical and subtropical regions

Parts of the plant we use:

- Aloe gel: It's the clear, gooey stuff from inside the leaf. People use it both inside and out.
- Aloe latex (aloe juice): This is the bitter, yellow stuff you get from under the leaf's skin. Mostly, it's used to help you poop.

#### Composition

- Polysaccharides: Acemannan, glucomannan, galactose derivatives (key bioactive agents)
- Vitamins: A, C, E, B1, B2, B6, B12, and folic acid
- Minerals: Calcium, magnesium, zinc, chromium, selenium, potassium, and copper
- Enzymes: Alkaline phosphatase, amylase, catalase, lipase

- Phenolic compounds: Aloin, aloe-emodin, chrysophanol (anthraquinones)
- Saponins and lignins: Contribute to cleansing and antiseptic actions
- Sterols: Campesterol,  $\beta$ -sitosterol, lupeol (anti-inflammatory and lipid-lowering effects)

Mechanism: Enhances insulin sensitivity, possesses anti-inflammatory and antioxidant properties.

Evidence: Studies involving diabetic patients indicated a substantial decrease in blood glucose levels after taking aloe vera. A clinical trial found a substantial decrease in HbA1c and fasting glucose levels after 4 - 8 weeks of aloe vera supplementation in patients with T2DM.

Clinical dosing: 100 - 200 mg of aloe vera per day.

### III. CHALLENGES AND LIMITATIONS

Using plants as medicine is getting pretty popular around the world as another way to deal with long-term illnesses like diabetes. Diabetes, where your blood sugar is too high because your body isn't using insulin right, is a huge problem these days. Modern medicine, like insulin and pills such as metformin, can help control blood sugar, but they can also have bad side that cost a lot, and might not work as well over time. So, using herbs and plants has become a good option because they can work in different ways, usually aren't as toxic, and are accepted across different cultures.

But, even with all of that, getting plant-based medicines into regular diabetes care has its issues. There are scientific, rules and ethical problems that get in the way. These problems make it tough to create, prove, and get everyone to accept plant-based treatments for diabetes. Knowing what these issues are is important, so we can make plant-based treatments more believable, safe, and helpful.

Plant Stuff: Why It's Not Always the Same

One big problem with plant-based medicine is that the stuff in plants can change a lot. How well a plant medicine works depends on things like:

- \* Different types of the same plant can be different.
- \* Where it's grown, the dirt, and the weather all matter.

\* When it's picked, how old the plant is, and how it's stored change things.

\* How you get the good stuff out and prep it matters. For example, how much berberine is in *Berberis aristata*, or how much gymnemic acids you get from *Gymnemasylvestre*, can be way different based on where it grew. This change affects if it works the same way each time. Unlike lab-made drugs with just one thing in them, plant medicines are mixes of stuff, so keeping them the same is hard.

Things get even trickier because sometimes people mix in the wrong plants or other junk. Since there aren't super strict rules everywhere for checking plant medicines, they might not work the same each time, and might even be risky.

Why consistent medicine is hard to make, how much to give, and how well it lasts

Making drugs the same way every single time is super important. That way, you get something that's good quality, safe, and works how it should. But with plant-based meds, it's really hard to make them exactly the same each time. That's because they have lots of different stuff in them. It's also tough to figure out which part of the plant is actually doing the work.

A lot of plant-based medicines don't have clear instructions on how much to take. Usually, the amount to use comes from old traditions instead of real science. We often don't have studies that show how different amounts affect you or how your body handles the medicine. This can make it tricky to use these medicines correctly. Plus, the amount of good stuff in these medicines can change between different brands. This might mean you don't get enough, or you get too much, which can either mean it doesn't work or it makes you sick.

The stuff in plants that makes them work can also break down when they're being made or stored. This means they might not be as strong after a while. Without good ways to test what's in them (like using machines that check chemicals), it's hard to make sure each batch is the same.

A lot of good plant-based chemicals don't get absorbed well by the body.

For example, curcumin (from turmeric), berberine, and resveratrol are great for diabetes in lab tests. But, they don't work as well in real life because they don't get absorbed well in the gut and get broken down quickly.

Because of this absorption issue, it's hard to turn them into real medicines that work. There are new methods like nanoparticles and liposomes that can help with absorption. But these methods can be expensive and developing countries don't use them enough.

One big problem is that we don't fully get how plant-based medicines fight diabetes.

Unlike man-made drugs like metformin that target specific things in the body, these medicines tend to work in many ways at once. They might boost insulin, help the body use glucose better, slow down how we digest carbs, fight stress, and protect cells in the pancreas.

This multi-way approach is good for a tricky disease like diabetes, but it makes proving how well these medicines work tough. A lot of research is done on animals or in labs, and it's not clear if the same things happen in people. Plus, studies on people often have different designs, not many people take part, and some don't use fake pills as a control, which makes the proof less strong. So, even though plant-based diabetes treatments show good results, they often don't get approved because there's not enough solid science.

Thinking about safety and mixing herbs with meds  
Lots of people think natural medicines from plants are automatically safe. But that's not always true. Herbs can actually be risky if you don't use them right, or if you take them with other medicines. Bad reactions can happen because of:

- Stuff like lead, bug spray, or germs messing up the herbs.
- People using the wrong plant.
- Taking too much of a strong herb for too long (like certain things in Aloe).
- Herbs messing with diabetes medicines and causing low blood sugar.

For instance, stuff like Ginseng, Aloe vera, and Fenugreek can make insulin or diabetes pills work too well, and that could cause someone's blood sugar to drop way too low. It's also risky because we don't always have good studies on herb safety, and labels don't always tell you when you shouldn't use them or mix them with other drugs.

#### IV. REGULATIONS AND POLICY PROBLEMS

Rules for herbal medicines are all over the place across different countries. A lot of places treat herb stuff like

food extras instead of real medicine, so they don't have to test it as hard before selling it. Because of this, the rules are a mess. The same plant stuff can be sold as a health thing in one country, but needs a doctor's note in another.

Also, because there's no worldwide system for watching if herbal medicines are safe after they're sold, it's hard to keep track of any problems. Groups like the WHO, US FDA, and EMA have tried to make rules for making sure these products are good quality, but it's not the same everywhere. It's especially tough in poorer countries, where most of these herbal things are made and sold.

Some tricky intellectual property and ethical issues

A lot of plant-based medicine comes from the know-how of native and local communities. But protecting this knowledge is a real debate. Too often, drug companies take advantage of old recipes without giving anything back to the people who came up with them. This is often called biopiracy.

Also, because there aren't many laws protecting traditional knowledge, it can stop local communities from coming up with new ideas. Another tricky thing is getting proper consent and input from communities when testing these medicines.

#### V. ECONOMIC AND INFRASTRUCTURAL LIMITATIONS

Making legit, tested herbal medicines costs a lot for research, quality checks, and trials. A lot of herbal businesses, mostly in poorer countries, don't have the right setup for making stuff well and testing it right. Not enough money and not enough help from the government slow down big clinical tests.

Plus, because you can't own plants as they are, drug companies usually aren't that into making herbal medicines. They'd rather grab one thing from the plant, tweak it so they can get a patent, and then sell that. That means less money goes into whole-plant medicines.

Lack of Expertise and Unqualified Professionals

Doctors often don't learn much about herbal medicine in school, which makes them wary of suggesting herbal stuff. Also, patients might use herbal supplements the wrong way, like mixing them with their meds without asking a doctor. Because

healthcare people don't get solid training in how herbs work, it's hard for old-school and new-school medicine to see eye-to-eye.

## VI. CONCLUSION

Diabetes mellitus remains one of the most severe and prevalent metabolic disorders globally, has a significant impact on public health systems, and affects millions of lives. While conventional pharmacological therapies (both older, such as insulin analogues, metformin, sulfonylureas, and incretin-based medications and newer agents) continue to show progress, many treatments also have unsafe side effects or are cost prohibitive with limited patient compliance and other issues. Given this reality, phytomedicine has become a viable alternative and complementary model for diabetes management. Phytomedicine is derived from medicinal plants with traditional uses for centuries. As a holistic and multifactorial approach, the action of phytomedicine reduces not only hyperglycemia but also oxidative stress, inflammation, dyslipidemia, and pancreatic dysfunction associated with diabetes.

Phytomedicines have therapeutic implications in diabetes due to their wide range of bioactive constituents such as alkaloids, flavonoids, saponins, terpenoids, polyphenols, and glycosides that work synergistically on several molecular pathways. Phytomedicines improve insulin release, insulin sensitivity, inhibit carbohydrate-digesting enzymes, and protect pancreatic  $\beta$ -cells from oxidative effects. Moreover, phytomedicines are frequently associated with lower toxicity and greater patient acceptability due to their natural basis and established record of clinical use as herbal remedies for promoting health and wellbeing, where they are often formally described, including Ayurvedic Medicine, Traditional Chinese Medicine (TCM) and Unani medicine. These medical traditions advocate individualized treatment methods and pay consideration to other aspects of conventional medicine such as mind-body-spirit, integration that has a considerable philosophical resonance and an essential criteria in managing chronic ailments.

The embrace of phytomedicine should always be met with a scientific approach of caution, in light of prior hopeful preclinical and clinical perspectives. This caution is valuable as there are still many obstacles and

limitations clinically or otherwise to full acceptance in evidence-based to support and permit a full range of plant therapies within main stream medicine. Concerns related to plant variability, absence of standardized preparation methods, poor bioavailability of phytochemicals, and lack of substantiation through large-scale randomized controlled trials hinder further credibility as well. Although the multi-component nature of herbal extracts can be beneficial to synergistic effects, it presents barriers to determining active principles, reproducibility of multi-component materials, and dosage standards.

Recent developments in phytopharmaceutical technology and nanomedicine has begun to address some of these limitations. Nanocarriers such as liposomes, nanoparticles, and phytosomes are being developed to resolve poor solubility of phytoconstituents such as curcumin and berberine, and enhance bioavailability and targeted delivery. Advanced analytical methods such as HPLC, LC-MS/MS, and DNA barcoding are being used for the authentication, standardization, and quantification of herbal constituents. Systems and network pharmacology are also advanced approaches that provide better understanding of the multitargeted mechanisms of phytochemicals, providing science based research to support rational formulation design and merit based validation of success.

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