ROLE OF FENUGREEK SEEDS IN GLYCEMIA: A REVIEW

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ABSTRACT

Background: Fenugreek (*Trigonella foenum-graecum*) is increasingly being explored as a natural option to help manage blood sugar levels, especially in people with Type 2 Diabetes and impaired glucose tolerance. The seeds contain several important bioactive compounds, including galactomannan, trigonelline, 4-hydroxyisoleucine, saponins, and polyphenols, which work together to produce blood glucose–lowering effects.

Purpose: This review brings together information on the plant's pharmacognostic features, chemical composition, mechanisms of action, clinical evidence, and safety profile.

Findings: Fenugreek helps control blood glucose through multiple pathways. It slows down carbohydrate digestion and absorption, stimulates insulin release in a glucose-dependent manner, improves insulin sensitivity, inhibits key digestive enzymes, and reduces oxidative stress. Clinical studies and meta-analyses have reported improvements in fasting and post-meal blood glucose levels, glycated hemoglobin (HbA1c), and lipid parameters. Most studies have used doses in the range of 10–25 g per day of seed powder or equivalent extracts. However, differences in study design, preparation methods, and lack of standardized formulations lead to variability in results.

Conclusion: Although fenugreek shows strong potential as a supportive therapy, some challenges remain. These include limited evidence at the molecular level in human studies, lack of clear dosing guidelines, and insufficient long-term safety data. This review highlights these gaps while combining traditional knowledge with modern scientific findings. Future research should focus on standardizing extracts, conducting large-scale clinical trials, and developing improved formulations to enhance absorption and therapeutic effectiveness.

Keywords: Fenugreek; *Trigonella foenum-graecum*; Diabetes; 4-hydroxyisoleucine; Galactomannan; Insulin; Antihyperglycemic.

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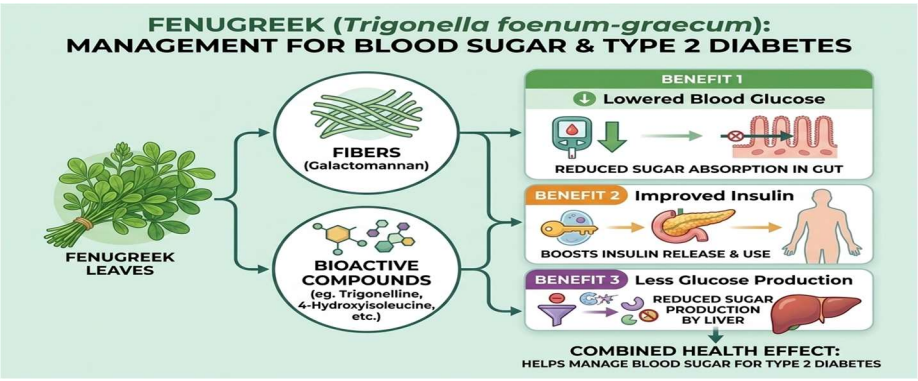

Figure 1: Graphical abstract

Introduction

Fenugreek (Trigonella foenum-graecum) is a self-pollinating herbaceous plant of the family Fabaceae. This largely cultivated annual herb is believed to be native to North Africa and India. Today it is cultivated worldwide in almost every continent. Fenugreek is one of the major cash crops of India. It is cultivated for its seeds and leaves in many Indian districts. Fenugreek is widely used in the spice industry and also finds use in almost every traditional and modern system of medicine. Fenugreek is classified as a nutraceutical and functional food, due to its therapeutic value and nutritional profile.

Fenugreek seeds are a rich source of proteins, carbohydrates and fiber, mucilage and a number of bioactive phytochemicals. Fenugreek seeds are used to stabilize and emulsionze food and pharmaceutical formulations. Fenugreek is a popular medicinal plant. It is used to management of weakness, inflammation, Diabetes mellitus, and dyspeptic disorders. Fenugreek seeds and leaves are traditionally used medicinally for Antidiabetic, Antihyperlipidemic, Antihypercholesterolemic, Antimicrobial, Antioxidant, and Anticancer activities.

The three-angled pod shape and flower of Trigonella inspired their name, as the ancient Greeks called podded plants having similar shapes 'trigonon'. It is grown in a variety of climates and soils, hence the reason it is cultivated in a variety of places such as India, Egypt, China, Pakistan, Iran, Afghanistan, Canada, Argentina, and the United States. India is a leading fenugreek grower, but due to its use in the food and traditional medicine of the region, a lot of the country's fenugreek is grown and used in the country.

Fenugreek seeds (*Trigonella foenum-graecum*) have been extensively studied for their ability to regulate blood glucose levels, particularly in individuals with diabetes and impaired glucose tolerance. These seeds are rich in bioactive constituents such as soluble fiber, alkaloids, amino acids, saponins, and flavonoids, which collectively contribute to multiple pharmacological effects supporting glycemic control. Due to these multifactorial actions and their natural origin, fenugreek is increasingly considered a complementary therapy alongside conventional antidiabetic treatments.

Diabetes mellitus is a chronic metabolic disorder characterized by elevated blood glucose levels resulting from impaired insulin secretion, insulin action, or both. Hyperglycemia is the hallmark of uncontrolled diabetes and contributes to long-term damage to organs such as the nerves, kidneys, eyes, and cardiovascular system.

The global prevalence of diabetes has increased significantly, affecting approximately 14% of adults worldwide, compared to about 7% in 1990. A substantial proportion of affected individuals, particularly in low- and middle-income countries, remain untreated, leading to increased morbidity and mortality.

Symptoms of Type 2 Diabetes often develop gradually and include excessive thirst, frequent urination, fatigue, blurred vision, and unintended weight loss. If not adequately managed, the disease can lead to complications such as neuropathy, nephropathy, retinopathy, and cardiovascular disorders.

Despite extensive research, variability in clinical outcomes, lack of standardized formulations, and limited mechanistic depth at the molecular level restrict the consistent therapeutic application of fenugreek. Therefore, this review critically evaluates its phytochemical composition, mechanisms of action (including cellular pathways), clinical evidence, and safety profile. The novelty lies in integrating mechanistic insights with clinical findings to identify research gaps and guide future pharmaceutical development.

Fenugreek is a nutritious food and an excellent source of starch, protein, and dietary fiber, as well as various vitamins, and minerals. The podded plant having seeds is an excellent sourse of soluble fiber and has varied minerals such as sodium, potassium, calcium, and magnesium, and of metalloids such as iron and zinc. It is a good sourse of vitamins, and has many healthful, antioxidant compounds such as vitamin C, and β-carotene. Thus, fenugreek can be implicated for treating metabolic and chronic diseases. [1-10, 68-72]

Table 1: Pharmacognostic, Phytochemical, and Traditional Uses of Fenugreek [6-10, 37-40]

Pharmacognostic & Botanical Details	
Biological Source	Dried ripe seeds of *Trigonella foenum-graecum* L.
Family	Fabaceae (Leguminosae)
Macroscopic Look	Hard, pebble-like, rhomboidal seeds; dull yellow to brownish-yellow.
Odour & Taste	Strong, maple-like spicy aroma; bitter and mucilaginous taste.
Key Microscopy	Palisade epidermal cells, hour-glass hypodermis, polyhedral endosperm.
Active Compounds	Mucilage, Trigonelline (alkaloid), Diosgenin (steroidal saponin).
Traditional Use	
Diabetes Control	Seeds soaked overnight; the water is drunk raw on an empty stomach.
Milk Production	Concentrated seed teas or boiled gruels fed to postpartum mothers.
Digestive Relief	Seeds chewed directly or swallowed to coat stomach ulcers with mucilage.
Skin & Wound Care	Ground seed powder mixed with warm water to form a paste poultice.
Kidney Tonic	Decoctions used in Chinese medicine to warm the kidneys and ease cramps.

Table 2: Chemical Components Contributing to the Morphology and Internal Structure of Fenugreek Seeds [6-10, 37-40]

Plant Part / Structural Feature	**Chemical Constituent**	**Role in Morphology and Internal Structure of Fenugreek**
Seed coat (Testa)	Cellulose	Forms the major framework of the seed coat and provides rigidity, hardness, and mechanical strength. It protects the inner tissues from physical injury and environmental stress.
Seed coat epidermis	Lignin	Strengthens epidermal and palisade cells by thickening cell walls, thereby improving durability and resistance against microbial invasion and

		mechanical damage.
Mucilaginous layer	Galactomannan	Absorbs water and forms a gelatinous mucilage layer around the seed, aiding hydration, swelling, and protection during germination.
Endosperm	Galactomannan	Serves as a carbohydrate reserve that supplies energy during seed germination and early seedling growth.
	Storage proteins	Provide amino acids and nitrogen required for embryo nourishment and metabolic activity during germination.
Cotyledons	Fixed oils	Function as stored energy reserves utilized during seed germination and development of the young plant.
	Proteins	Support tissue development and biosynthesis of new cellular components during germination.
Palisade cells	Cutin	Forms a protective waterproof barrier that reduces moisture loss and protects against environmental damage.
	Lignified materials	Provide compact arrangement and structural rigidity to the seed coat.
Hypodermal hour-glass cells	Hemicellulose	Maintains flexibility and contributes to the characteristic microscopic appearance of fenugreek seeds.
	Lignin	Increases mechanical strength and stability of the hypodermal tissue.
Embryo	Amino acids	Participate in protein synthesis and

		metabolic processes necessary for seed germination.
	Phospholipids	Form cellular membranes and support metabolic and enzymatic functions in developing tissues.
Mucilage-containing tissues	Mucilage polysaccharides	Facilitate water retention, seed swelling, and lubrication during germination.
Storage cells	Diosgenin	Acts as a defensive phytochemical and serves as a precursor for steroidal compounds with medicinal importance.
	Saponins	Protect the seed from microbial attack and contribute to pharmacological activities such as hypoglycemic and hypolipidemic effects.
	Flavonoids	Protect cellular
Phenolic-containing tissues		structures against oxidative stress and contribute to antioxidant defense mechanisms.
	Tannins	Provide antimicrobial protection and help preserve seed integrity.
Volatile oil fraction	Sotolone	Responsible for the characteristic maple syrup–like aroma and flavor of fenugreek seeds.
Cell wall matrix	Pectic substances	Help maintain cell adhesion, flexibility, and hydration within seed tissues.
Seed tissues	Minerals (Ca, Mg, Fe, Zn)	Support enzymatic activities, structural stability, and metabolic processes during germination and growth.

Phytochemical Composition Relevant to Glycemic Control

Fenugreek seeds (*Trigonella foenum-graecum*) contain a variety of bioactive compounds that are important for their blood glucose–lowering effects. Key constituents include galactomannan, a soluble dietary

fiber; trigonelline, an alkaloid; and 4-hydroxyisoleucine, a distinctive amino acid. In addition, fenugreek provides saponins and polyphenolic compounds that contribute to antioxidant activity and metabolic regulation. These components act together to influence glucose metabolism, insulin secretion, and overall glycemic balance.

A major mechanism by which fenugreek helps control blood glucose is through its high content of soluble fiber, particularly galactomannan. When consumed, this fiber forms a gel-like substance in the gastrointestinal tract, which slows gastric emptying and delays the digestion and absorption of carbohydrates. As a result, the rise in blood glucose after meals is more gradual, helping to maintain stable glycemic levels. This effect is especially useful for individuals with Type 2 Diabetes, who often experience sharp increases in blood glucose following food intake.

Another important component, 4-hydroxyisoleucine, plays a significant role in stimulating insulin release from pancreatic β-cells. Its action is glucose-dependent, meaning it enhances insulin secretion primarily when blood glucose levels are high. This reduces the likelihood of hypoglycemia, which is a common concern with some anti-diabetic medications. Additionally, this amino acid may improve insulin sensitivity, allowing body tissues to utilize glucose more effectively.

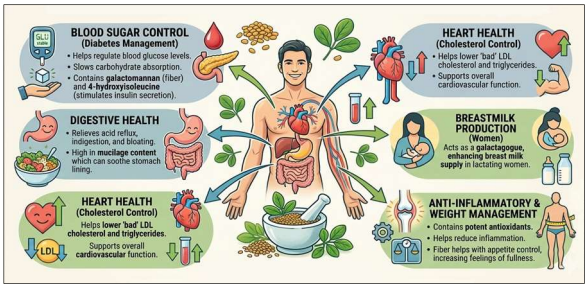

Figure 2: Medicinal benefits of Fenugreek in human health

Fenugreek also affects carbohydrate metabolism by inhibiting digestive enzymes such as α-amylase and α-glucosidase. These enzymes are responsible for breaking down complex carbohydrates into simple sugars. By reducing their activity, fenugreek slows the conversion of carbohydrates into glucose, thereby limiting the rate at which glucose enters the bloodstream. This mechanism is comparable to the action of certain oral anti-diabetic drugs. [6-10, 37-40]

In addition to its direct effects on glucose metabolism, fenugreek exhibits antioxidant and anti-inflammatory properties. Persistent Hyperglycemia is known to increase oxidative stress and inflammation, both of which contribute to the development of diabetic complications. The flavonoids and polyphenols present in fenugreek help neutralize free radicals and reduce cellular damage. These effects may also protect pancreatic β-cells and support better insulin function. Table 1 summarizes the major bioactive compounds and their mechanisms involved in glycemic control. [21, 27–33, 41–50, 63–67]

Table 3: Bioactive Components and Mechanisms of Fenugreek in Glycemic Control

Component	**Active Compound**	**Mechanism of Action**	**Effect on Glycemia**
Soluble Fiber	Galactomannan	Delays gastric emptying and carbohydrate absorption	Reduces postprandial glucose spikes
Amino Acid	4-Hydroxyisoleucine	Stimulates glucose-dependent insulin	Improves insulin response and glucose uptake

		secretion	
Alkaloid	Trigonelline	Enhances insulin sensitivity and glucose metabolism	Lowers blood glucose levels
Saponins	Diosgenin and related compounds	Modulates lipid and glucose metabolism	Improves glycemic and lipid profile
Digestive Enzyme Inhibitor	—	Inhibits α-amylase and α-glucosidase	Slows carbohydrate digestion
Polyphenols	Flavonoids, Polyphenols	Reduces oxidative stress and inflammation	Protects β-cells and supports insulin function

Clinical Evidence Supporting Glycemic Effects

A substantial body of clinical and experimental research supports the role of fenugreek (*Trigonella foenum-graecum*) in improving glycemic control. Early clinical investigations demonstrated that supplementation with fenugreek seed powder (typically 10–25 g/day) in patients with Type 2 Diabetes resulted in significant reductions in fasting blood glucose and improved glucose tolerance. For instance, a controlled study by Sharma RD and colleagues reported that defatted fenugreek seed powder significantly lowered fasting blood glucose and urinary glucose excretion in diabetic patients over a period of several weeks.

Further evidence from randomized and non-randomized clinical trials indicates that fenugreek supplementation can also reduce postprandial glucose levels and improve glycated hemoglobin (HbA1c), a key marker of long-term glycemic control. A study conducted by Gupta A et al. showed that fenugreek seed extract administered for 8–12 weeks significantly improved glycemic indices and insulin sensitivity in patients with mild to moderate diabetes. Similarly, research by Madar Z demonstrated that incorporation of fenugreek fiber into the diet delayed carbohydrate absorption and reduced post-meal glucose excursions.

In addition to glycemic effects, several studies have reported improvements in lipid profiles. Clinical trials have shown reductions in total cholesterol, low-density lipoprotein (LDL), and triglyceride levels following fenugreek supplementation, which is beneficial given the strong association between diabetes and dyslipidemia. These combined effects suggest that fenugreek may help in managing both hyperglycemia and associated metabolic complications.

Meta-analyses and systematic reviews have further supported these findings, indicating that fenugreek consumption leads to modest but significant improvements in fasting blood glucose and HbA1c levels. However, the magnitude of these effects varies across studies due to differences in dosage, formulation (whole seeds, powder, or extract), duration of treatment, and study populations.

Despite promising results, limitations such as small sample sizes, short study durations, and lack of standardization in fenugreek preparations highlight the need for more rigorous, large-scale randomized controlled trials. Future research should focus on

establishing optimal dosing regimens, understanding long-term safety, and confirming efficacy across diverse populations. [11–25, 51–56, 74]

Safety and Limitations

Fenugreek (*Trigonella foenum-graecum*) is usually safe when taken in normal food amounts. However, taking large amounts may cause stomach problems like bloating, gas, or diarrhea because it contains a lot of fiber. Some people may also notice a sweet, maple-like smell in their sweat or urine, which is harmless but may feel uncomfortable.

Fenugreek can increase the effect of diabetes medicines, which may lead to Hypoglycemia. So, blood sugar levels should be checked regularly when it is taken with insulin or other antidiabetic drugs. It may also slightly thin the blood, so there is a small risk of bleeding if used with blood-thinning medicines. Allergic reactions are rare but can happen, especially in people who are sensitive to legumes.

Special care should be taken by pregnant women, as high amounts may affect the uterus. Also, differences in how fenugreek is prepared and used can lead to different results in studies. Therefore, even though fenugreek is promising, more research is needed to confirm its safety and proper use over the long term. [36, 56, 57, 75]

Conclusion

This review paper can conclude that fenugreek (*Trigonella foenum-graecum*) plays a significant role in glycemic control through multiple mechanisms, including delayed carbohydrate absorption, enhanced insulin secretion, improved insulin sensitivity, and antioxidant effects. These properties support its potential as an adjunct therapy in the management of Type 2 Diabetes.

However, variability in study design, lack of standardized formulations, and inconsistent dosing limit its clinical application. Therefore, further large-scale, long-term studies, along with standardization of extracts and advanced pharmaceutical formulations, are required to confirm its efficacy and ensure safe and effective use in clinical practice.

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