Int.J.Curr.Microbiol.App.Sci (2025) *14*(10): 98-105

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 14 Number 10 (2025)**
Journal homepage: http://www.ijcmas.com

Review Article

https://doi.org/10.20546/ijcmas.2025.1410.009

Understanding Therapeutic Applications of Fenugreek (*Trigonella foenum graecum* L.) With Reference to Indian Knowledge System

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Keywords

Trigonella foenum greacum L, Bioactive, Anti-Inflammatory, Antioxidant.

Article Info

Received:
08 August 2025
Accepted:
29 September 2025
Available Online:
10 October 2025

A B S T R A C T

The current study investigates the potential of *Trigonella foenum greacum L.* as a new alternative in terms of natural bioactive components. Fenugreek is abundant in nature and spread over a wide geographical area. It has been a vital part of our Indian Knowledge System for therapeutic treatment. Traditional use often supported by modern studies demonstrates its curative potential in areas like reducing inflammation, glycaemic control, improving cardiovascular markers, lactation, lipid-lowering effects, antioxidant, anti-obesity, anticancer benefits. Various studies have established its medicinal properties like a carminative, gastric stimulant, antidiabetic, galactogogue, hypocholesterolemic, antilipidemia, antioxidant, hepatoprotective, anti-inflammatory, antibacterial, antifungal, antiulcer, anticarcinogenic etc. Still larger and longer clinical studies are essential before broad therapeutic endorsement.

Introduction

Nature is the ultimate source of medical elements for thousands of years and plants have long been used as traditional herbal medicines to treat various health issues (Chaachouay and Zidane, 2024). Interest in research on traditional medicine systems like Ayurveda and other ancient methods not only integrates the Indian Knowledge system for better treatment of ailments but also provides time and cost-efficient results for drug discovery (Katiyar *et al.,* 2012). In nature a lot of medicinal plants are available and have been studied for both nutraceutical as well as pharmaceutical values and one of the most frequently used is fenugreek since ancient times. Fenugreek has proven rich bioactive compounds with diverse therapeutic and pharmacological potential benefits (Ruwali *et al.,* 2022).

Fenugreek (*Trigonella foenum-graecum* L.) is a seed spice, used to enhance flavour, colour and texture of food and is employed for medicinal purposes in many traditional systems. The leaves and seeds of fenugreek are commonly used for flavouring and as a spice in curries due to their strong flavour and aroma (Kakani and Anwar, 2012). A number of epidemiological studies and laboratory research have unravelled the biological actions

of fenugreek. Fenugreek has been used for numerous indications, including labour induction, aiding digestion, and as a general tonic to improve metabolism and health (Yadav and Baquer, 2014).

Fenugreek phytochemicals show high preventive and nutraceutical potential against common chronic diseases. There are sufficient evidences which show that there are multiple mechanisms of actions, mediated by distinct bio-actives making it a good nutraceutical and a functional food (Alu'datt *et al.,* 2024). Preliminary animal and human trials suggest possible hypoglycaemic and antihyperlipidemic properties of oral fenugreek seed powder (Basch *et al.,* 2003). It also works as an antidiabetic, anticarcinogenic, antioxidant, antibacterial, anti-anorexia agent. It is a known gastric stimulant and works as a remedy for hypocholesterolaemia and hypoglycaemia (Rao and Sharma, 1987).

Nutritional Constituents

The pharmacological actions of fenugreek are attributed to diverse array of phytoconstituents and the phytochemical analysis reveals the presence of steroids, alkaloids, saponins, polyphenols, flavonoids, lipids, carbohydrates, amino acids, fibres, and hydrocarbons. (Kalyan *et al.,* 2017). Mature seeds contain amino acid, fatty acid, vitamins, saponins, folic acid, glycolipids, oleic acid, linolenic acid, linoleic acid, choline, vitamins A, B1, B2, C, nicotinic acid, niacin and many other functional elements (Ahmad *et al.,* 2016).

Fenugreek seeds are rich in protein (25·5%), fat (7·9%), unavailable carbohydrate (48%), mucilaginous matter (20%) and saponins (4·8%). 100 g of seeds provide more than 65% of dietary fibre due to its high fibre content. It is used as a food stabilizer, adhesive and emulsifying agent and its protein is found to be more soluble (91.3%) at alkaline pH of 11 (Meghwal and Goswami, 2012).

The chemical composition of fenugreek crop includes moisture, ash, protein, mucilage, lipids, alkaloids (Trigonelline), amino acids (4-hydroxyisoleucine), saponins (Diosgenin), flavonoids (Quercetin, Rutin, And Vitexin), fibres (soluble dietary fibre), polyphenols, coumarin, vitamins (Vitamin C), and minerals (Calcium, Zinc, Sulphur, And Phosphorus) (Niknam *et al.,* 2021). Fenugreek seeds contain the major free amino acid 4-hydroxyisoleucine (4-OH-Ile), which has been characterized as one of the active ingredients for blood glucose control (Flammang *et al.,* 2004).

Phytochemical Composition and Bioactive Compounds

The phytochemical analysis (Sauvaire *et al.,* 1991; Fuller and Stephens, 2015; Ahmad *et al.,* 2016) of Fenugreek reveals the presence of:

Alkaloids (Trigonelline, Choline, Carpaine) which have neuroprotective, anti-diabetic, and anti-inflammatory and hypoglycaemic properties.

Saponins (Fenugrin, Foenugracin, Glycoside, Yamogenin, Trigonoesides, Smilagenin, Gitogenin, Sarsasapogenin, Yuccagenin, Hederagin, Diosgenin, Tigonenin, Neotigogenin) which helps lower cholesterol, regulate blood glucose, have immunomodulatory and anti-obesity properties.

Flavonoids (Lysine, Histidine, 4-Hydroxyisoleucine, Tryptophan, Tyrosine, Cystine, Arginine) which are anti-oxidant, reduces oxidative stress, inflammation, protects against cardiovascular diseases, anti-cancer.

Coumarins (Methyl Coumarin, Trigo-Coumarin, Trimethyl Coumarin) are effective against various cancers.

Terpenoids (Furanocoumarins) are anti-inflammatory, anti-microbial and anticancer.

Amino Acids Proteins and Enzymes (Lysine, Histidine, 4-Hydroxyisoleucine, Tryptophan, Tyrosine, Cystine, Arginine) have insulin-sensitizing effects, helps with indigestion and produces anti-inflammatory responses.

Fatty Acids (Linoleic Acid, Oleic Acid) help reduce inflammation, improves cardiovascular health and enhances skin.

Vitamins and Minerals (Vitamins A, B, C, and K, Iron, Magnesium, Calcium, And Potassium) provide nutritional value and have therapeutic effects.

Pharmacological Properties and Therapeutic Applications

Antidiabetic and Hypoglycaemic Effects

Several clinical trials showed that fenugreek seeds improve blood glucose levels, insulin resistance, insulin

sensitivity, and lipid profiles making it a potential therapy for diabetes. (Kooshki *et al.,* 2018; Sarker, 2024). Sauvaire *et al.,* (1998) reported that fenugreek seeds contain a free unnatural amino acid, 4-hydroxyiso-leucine, which increases glucose-induced insulin release in pancreatic islet cells of humans and rats. Fenugreek stimulates tyrosine phosphorylation of the insulin receptor and enhances glucose uptake into cells.

Studies identify that defatted portion of fenugreek seed induce a hypocholesterolemic and hypertriglyceridemia effect (Valette *et al.,* 1984; Gupta *et al.,* 2001).

Anticancer Effects

Phytochemicals like coumarins, furanocoumarins, flavonoids are known to follow multi-target anti-cancer mechanisms across various cancers. Fenugreek extracts show selective cytotoxicity against cancer cell lines like breast, pancreatic, neuroblastoma etc., potentially via apoptosis induction pathways like p53, without affecting normal cells (Visuvanathan *et al.,* 2022). A study by Amin *et al.,* (2005) shows a potential protective effect of fenugreek seeds against 7, 12-dimethylbenz(α) anthracene (DMBA)-induced breast cancer in rats.

The antineoplastic and anti-inflammatory effect of *Trigonella foenum graecum* seed extract has been evaluated in a study by Sur *et al.,* 2001. The alkaloid trigonelline and the crude extract of fenugreek can induce apoptosis as well as S phase arrest on the cell line displaying their *in vitro* anticancer effects (Varadrajan *et al.,* 2023).

Antioxidant and Anti-inflammatory Effects

Fenugreek reduces inflammation in various parts of the body benefiting conditions like arthritis and respiratory issues by free-radical scavenging and protecting against oxidative damage. It helps in the management of metabolic diseases and inflammatory disorders (Abedinzade, 2015).

Anti-inflammatory actions of fenugreek are linked to phytoestrogenic components like diosgenin. Its antioxidant potential protects the organs such as liver and pancreas against the oxidative damage induced by diabetes (Sankar *et al.,* 2012).

Kaviarasan *et al.,* (2007) evaluated the Fenugreek seeds for their antioxidant activity using various in vitro assay systems and deduced that fenugreek seeds protect cellular structures from oxidative damage.

The effect of fenugreek seeds (*Trigonella foenum graecum*) on blood lipid peroxidation and antioxidant status in alloxan diabetic rats was studied by Ravikumar and Anuradha, (1999).

Dixit *et al.,* (2005) showed that disrupted free radical metabolism in diabetic animals may be normalized by fenugreek seed supplementation in the diet.

Cholesterol and Lipid Regulating Effects

Fenugreek seeds help to lower serum triglycerides, total cholesterol and low-density lipoprotein cholesterol (Hannan *et al.,* 2007).

Anti-oxidants from seeds exhibit hypocholesterolemic abilities and control high blood cholesterol. Moreover, the soluble fibre in fenugreek seeds binds to cholesterol molecules in the gut, preventing their absorption into the bloodstream, and help lower total cholesterol and LDL (low-density lipoprotein) cholesterol levels, reducing the risk of heart disease (Wang *et al.,* 2023).

Roberts *et al.,* (2011) mentions cholesterol regulatory properties of fenugreek compounds, specifically dietary fibres.

Neurological effects

Few studies have reported the beneficial role of fenugreek and its constituents on neurological health. It exerts positive impact on pathological symptoms of Alzheimer's disease and is neuroprotective, antidepressant and antianxiety in nature.

Fenugreek is found to have modulatory effects on cognitive functions and Parkinson's disease (Nathan *et al.,* 2014; Zameer *et al.,* 2017).

Immunomodulatory Actions

Immunomodulatory effect of aqueous extract of *Trigonella* significantly increases phagocytic capacity of macrophages and is therefore extensively used in several Ayurvedic and Unani drugs. It helps to support immune system in maintaining health and is an established immunostimulant (Bin-Hafeez *et al.,* 2003).

Cardiovascular Health

Fenugreek has been shown to have cardioprotective effects, including improving lipid profiles, reducing high blood pressure and preventing the buildup of arterial plaque. Trigonelline helps in detoxification of free radicals, high lipid peroxidation and prevents myocardial injuries (Panda *et al.,* 2013).

It is an efficient agent against cardiotoxicity and atherosclerosis (Feki *et al.,* 2019a). Pradeep and Srinivasan, (2018) found that combination of fenugreek seeds and onion offers higher beneficial influence in ameliorating cardiac damage accompanying diabetes while Mujthamba and Srinivasan, (2015) suggested that the combination of fenugreek seeds and garlic have a beneficial influence in exerting cardioprotective effect.

Hepato-Protective and Renal-Protective Action

Fenugreek seeds aqueous extract has been found effective in hepatotoxicity and genotoxicity and heals liver (Feki *et al.,* 2019b). Reddy and Srinivasan, (2009) concluded that the fenugreek seeds not only reduce the induction but also regress the preformed gall stones, thus having an anti-lithogenic effect through anti-hypercholesterolemic action in mice.

It is also found to act as an antioxidant and reduce oxidative stress and also inhibits accumulation of oxidized DNA in the kidney, thus acting as a potential drug for the prevention and therapy of diabetic neuropathy (Xue *et al.,* 2011).

Antimicrobial and Antifungal Activities

The essential oils and alkaloids in fenugreek help fight infections and promote gut health due to their anti-microbial and anti-fungal effects. The antimicrobial and anti-inflammatory nature of fenugreek has been evaluated in various organisms such as *Streptococcus mutans, Lactobacillus, Enterococcus faecalis, and Candida albicans*. Fenugreek gel can be used as an alternative periodontal dressing to reduce postoperative inflammation (Sindhusha *et al.,* 2023).

Hormonal Balance and Lactation

Fenugreek is traditionally known for its galactagogue properties, promoting milk production in breast feeding women and is used to help balance hormones, especially women hormonal health. Ghasemi *et al.,* (2015) found that herbal tea of fenugreek seed improves the signs of breast milk sufficiency.

Fenugreek husked seed extract has been found to reduce menopausal symptoms in healthy women (Steels *et al.,* 2017). Reports show that fenugreek seeds provide an estrogenic effect resulting in enhanced breast size. In vitro and in vivo studies by Sreeja and Anju, (2010) demonstrate its suitability as an alternative to hormone replacement therapy.

Topical uses, Skin and Hair loss Protection

The seed extract of Fenugreek reduces skin irritation and pain. Seed powder paste leads to healing of the skin, moisturizes it, smoothens it and causes whitening. Current research suggests that topical application with the extract contributes to maintaining a healthy scalp and can be used as a therapy for dandruff and other types of scalp irritation. It can also be used for treatment of hair loss in women and men (Schulz *et al.,* 2006).

Weight Management and Obesity

Fenugreek's role in weight management is linked to its appetite suppressing properties. Saponins and fibre contribute to the feeling of fullness, reducing food intake and ultimately assisting in weight loss. *Trigonella* leaves are a good source of bioactive compounds like quercetin, catechin, cinnamic acid, and coumaric acid, along with a high content of soluble fibres and is suggested for body weight control (Aylanc *et al.,* 2020).

Other medicinal effects

Fenugreek seed gum is rich in galactomannan and has prebiotic potential. It shows resistance to digestion yet full fermentability by gut microbiota in vitro. Fenugreek seed gum satisfies two essential conditions of a prebiotic: resistance to enzymatic digestion and being totally fermented by caecal bacteria (Zemzmi *et al.,* 2020)

Risk Profile

While fenugreek has many benefits, its usage may pose certain risks such as abortion, fertility issues, hypoglycaemia, allergic reactions and interactions with medications such as anticoagulants. Safety evaluations

indicate concerns particularly during pregnancy and in individuals with hormone-sensitive conditions. Allergic reactions after consumption of spices are well known. In Asia, fenugreek seeds are consumed as spices and also as medicine. Literature survey carried out does not reveal reports of allergic reactions to fenugreek although a few instances have been observed with severe allergy to fenugreek (Patil *et al.,* 1997).

Preliminary human trials report that the administration of fenugreek seems to be associated with possible clinical adverse effects including diarrhoea, dyspepsia, abdominal pain, flatulence and hypoglycaemia (Ouzir *et al.,* 2016).

In conclusion, this article is an attempt to describe the reported medicinal uses of *Trigonella foenum graecum* L. (Fenugreek) along with its phytochemistry and pharmacological aspects. Due to its proven beneficial medicinal effects, it can be considered as a potential nutraceutical. The clinical uses of fenugreek can be attributed to the rich chemical constituents it possesses. These phytochemicals make it a potent alternate for synthetic drugs, helping in alleviating dependence on them and expensive treatments to cure a large number of diseases.

It can be safely concluded that Fenugreek is having deep roots in Ayurveda and our Indian Knowledge System and has been used for therapeutic treatment since ancient times. Its bio active compounds have shown good results in maintaining blood sugar, reducing cholesterol, is anti-inflammatory and immunomodulatory in nature. Fenugreek aligns well with ethnomorphological practises, it is well documented and so holds a promising future in curing diseases. Further research and investigations are still needed to isolate the bioactive compounds from crude extract for specific drug development so that target specific treatment can be provided.

This integration of traditional practises and contemporary medicine proves that proper research studies along with planned clinical trials can be effectively utilized so that our Indian Knowledge System can be put to certified use as established by clinical trials and reports.

Author Contributions

Eshita Pandey (Corresponding Author): Conceived the original idea, wrote the manuscript, formal analysis, reviewing and validation; Rahul Awasthi: Wrote the manuscript, formal analysis, reviewing, and editing.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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How to cite this article:

Eshita Pandey and Rahul Awasthi. 2025. Understanding Therapeutic Applications of Fenugreek (*Trigonella foenum graecum* L.) With Reference to Indian Knowledge System. *Int.J.Curr.Microbiol.App.Sci.* 14(10): 98-105.
doi: https://doi.org/10.20546/ijcmas.2025.1410.009