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## Fenugreek seeds: Nutritional composition and therapeutic properties

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### Abstract

Fenugreek is a medicinal herb that is mainly found in the natives of the Middle East and South Asia where it is not only used as a medicine but also as a spice. The seeds of fenugreek have various health promoting benefits due to their nutritional composition and bioactive compounds present in it. It has a decent amount of fiber and protein, and has a balanced nutritional profile. The seeds are also high in essential vitamins and mineral such as, magnesium, manganese, iron, vitamin A, vitamin C, vitamin B, riboflavin, thiamine, and niacin. Fenugreek seeds are a potential remedy for diabetes control and prevention. The seeds contain fiber and other phytochemicals like polyphenols, saponins and flavonoids that may slow down the digestion and the body's absorption of glucose. Fenugreek seeds also contain anti-inflammatory qualities that aid in the relief of menstrual cramps and other menstrual-related issues. It also aids weight loss and controls cholesterol levels. This study paper is based upon the nutraceutical properties of fenugreek seeds, especially which could be beneficial for controlling the blood glucose levels. So, this study focuses on the hypoglycemic effects of fenugreek seeds in diabetic patients. Although different types of anti-diabetic or hypoglycemic drugs are available and most of them are beneficial in providing long-term glycaemic control, they are not free from some associated adverse side effects such as flatulence, cramps, diarrhoea, nausea, and gastrointestinal irritation. For the same reason, a phyto-medicine like fenugreek seeds, which is capable of treating the disease at early stages, but with fewer adverse effects and less expensive, will be of excellent help to the diabetic patients specially because of the extended belief that natural remedies cause less harm to the organism.

**Keywords:** Fenugreek seeds, diabetes mellitus, nutraceutical properties, hypocholesterolemic effect, antioxidant properties, anti-inflammatory properties, hypoglycemic properties

### 1. Introduction

Fenugreek (*Trigonella foenum graecum*) also known as Methi is an annual crop belonging to the subfamily Papilionacea, family Leguminosae (Fabaceae) (Ghosh *et al.*, 2015) [28]. It is an aromatic leguminous plant used as spice and flavouring additive in food preparation (Mandal *et al.*, 2016) [53]. The name fenugreek comes from the Latin word foenum-graecum, which means "Greek hay" (Petropoulos, 2002) [63]. The plant was originally used as fragrance (Snehlata *et al.*, 2012) [83]. *Trigonella* gets its name from an antique Greek word that means "little triangle" referring to the triangular shape of the little yellowish-white flowers (Mehrafarin *et al.*, 2011) [57]. The first recorded use of fenugreek is portrayed on an ancient Egyptian papyrus dated to 1500 B.C (Borchardt, 1999) [20]. Fenugreek is thought to have originated in the 'Old World' Mediterranean region or in parts of Asia but it was debatable (Acharya *et al.*, 2006) [2]. It is an ancient indigenous herb to the countries along the Mediterranean's eastern shores, and it is widely cultivated in India, Egypt, and Morocco (Snehlata *et al.*, 2012) [83]. The actual number of Fenugreek species has also been questioned. Linnaeus (taxonomists) estimated that there are 260 species of Fenugreek, but only 18 species of *Trigonella* are officially recognised (Acharya *et al.*, 2006) [2]. The majority of species, including *Trigonella foenum-graecum*, have  $2n = 16$  chromosomes (Acharya *et al.*, 2006) [2]. Some *Trigonella* species, however, have 18, 28, 30, 32, or 44 chromosomes (Acharya *et al.*, 2006) [2]. Medicinal species of the genus *Trigonella* are *Trigonella T. foenum-graecum*, *T. balansae*, *T. corniculata*, *T. maritima*, *T. spicata*, *T. occulta*, *T. polycerata*, *T. calliceras*, *T. cretica*, *T. caerulea*, *T. lilacina*, *T. radiata*, *T. spinosa* (Aasim *et al.*, 2018) [11].

Latin name of Fenugreek is *Trigonella foenum-graecum* L and seed is *Foenugraeci semen* (t (Petropoulos, 2002) [63]. Fenugreek is named differently in various countries, viz., Fenugrec, Trigonelle (French), Methi, Methika (Hindi), Bockshorklee, Bockshornsamen-seed (German), Fieno greco (Italian), Pazhitnik, Pazhitnik grecheskiy (Russian), Alholva, Fenogreco (Spanish), Koroha (Japanese), Hulba (Arabian), Halba (Malaya), K'u-Tou (China), Fenegriek

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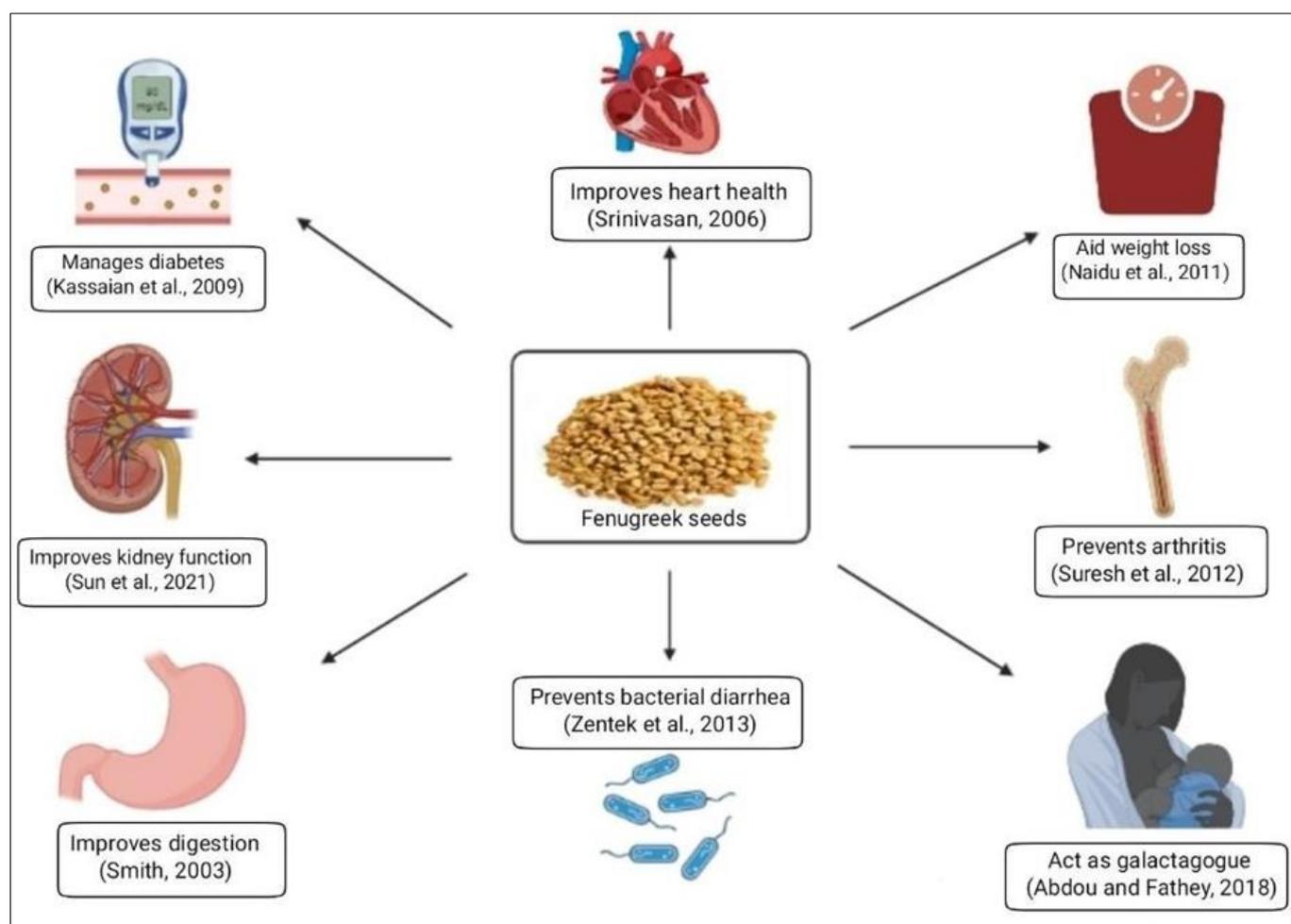
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(Dutch) and Alforva, Feno-grego (Portuguese) (Srinivasan *et al.*, 2006)<sup>[71]</sup>.

Macro and micro-nutrients play an important role in enzymatic activities of plant and their ultimately growth, yield and quality (Aishwath *et al.*, 2018)<sup>[7]</sup>. Each 100 g of fenugreek leaves will contain moisture (86%), protein (4.4%), fat (1%), fiber (1%), calcium (395 mg), magnesium (67 mg), phosphorus (51 mg), iron (16.5 mg), sodium (76 mg), potassium (31 mg), copper (260 mg), selenium (167 mg), chlorine (165 mg), carotene (2.3 mg), thiamine (40 mg), riboflavin (310 mg), nicotinic acid (800 mg), and vitamin C (52 mg) with traces of vitamin K (Table 2). Fenugreek seeds are aromatic, slightly bitter, carminative, galactagogue, antibacterial and may be eaten raw or cooked. Each 100 g fenugreek seeds contain the fiber portion consisting of both insoluble (30%) and soluble fraction (20%), which is usually galactomannan. It also contains carbohydrates (45-60%), proteins (20-30%), lipids (5-10%), which majorly consists of neutral lipids, namely, triglycerides (6.3%) and phospholipids (450 mg/100 g) (Acharya *et al.*, 2006)<sup>[2]</sup>. It is also constituted of pyridine alkaloids, flavonoids, amino acids, iron and calcium, saponins (0.6-1.7%), glycosides yielding steroidal sapogenins on hydrolysis, cholesterol and sitosterol, vitamin A, B1, C, nicotinic acids as well as volatile oils (0.015%) (Singh *et al.*, 2013)<sup>[73]</sup>. Fenugreek seeds are immensely

nutritious, and could greatly impact over all wellbeing when used as forage crops as well as for human consumption (Olaiya *et al.*, 2014)<sup>[62]</sup>. Due to its high fibre content, fenugreek seeds could be used as food stabilizer, adhesive and emulsifying agent to change the texture of food for some distinctive purposes (Khorshidian *et al.*, 2016)<sup>[44]</sup>. Fenugreek seeds are also used as a preservative as they are rich in antioxidants like vitamin E and vitamin E protects body tissue from damage which could be caused by substances called free radicals which can harm the cells, tissue and organs (Aher *et al.*, 2016)<sup>[8]</sup>. It is also a rich source of many important amino acids such as, leucine, tyrosine, aspartic acid, glutamic acid and phenylalanine (Syed *et al.*, 2020)<sup>[28]</sup>. In various medicinal applications, it works as anti-diabetic, anti-carcinogenic, anti-hypoglycemia and anti-hypocholesterolemia, antioxidant, antibacterial agent, gastric stimulant, and antianorexia agent (Aher *et al.*, 2016)<sup>[8]</sup>. Saponins and diosgenin present in fenugreek seeds are responsible for hypolipidemic and anti-diabetic action (Aher *et al.*, 2016)<sup>[8]</sup>. Moreover, fenugreek has a beneficial effect on cleansing the blood and as a diaphoretic, it is able to bring a sweat and help in detox the body (Sharara *et al.*, 2017)<sup>[77]</sup>. Fenugreek seeds also help in reducing the amount of calcium oxalate in the kidneys which causes kidney stones (Aher *et al.*, 2016)<sup>[8]</sup>.



**Fig 1:** Benefits of Fenugreek seeds

## 2. Plant morphology

*Trigonella foenum-graecum* genotypes differ in terms of morphology, growth habit, biomass, and seed production potential (Acharya *et al.*, 2006)<sup>[2]</sup>. It also differs in the

chemical elements contained in the seed, which can be used to improve Fenugreek through selection (Acharya *et al.*, 2006)<sup>[2]</sup>. The plant grows to a height of about three feet (Snehlata and Payal, 2012)<sup>[83]</sup>. The pods of *Trigonella foenum-graecum*

is a thin, light brown, sword-shaped of 10-15 cm with a curved beak-like tip and hairy each carrying 10-20 seeds and when mature colour of the seeds turn golden yellow (Acharya *et al.*, 2007) [3]. Fenugreek seeds are small (5 mm) long, hard, and brownish yellow in colour (Branch, 2013) [13]. They are toppled and have rhomboidal outline. Hilum and micropyle are situated in a small depression in the centre of one of the long, narrow sides (Yadav and Biyani, 2019) [89]. Hilum is distinctly visible as a whitish point and the depression diagonally divides the seed into two unequal lobes, the larger lobe containing two accumbent cotyledons and the smaller lobe where the radical is found. Both lobes are yellowish in colour, and surrounded by a darker, translucent endosperm, which separates the radicle from the cotyledons (Branch, 2013) [13].

*Trigonella foenum-graecum* being a legume crop, it can improve soil quality by fixing nitrogen from the atmosphere and reducing the demand for nitrogen fertilisers, lowering production costs (Acharya *et al.*, 2006) [2]. As Fenugreek is a dryland crop with minimal water requirements, it reduced the costs on irrigation and saved water (Mehrafarin *et al.*, 2011) [57]. Fenugreek is an excellent legume crop for including into short-term crop rotations because of these characteristics (Mehrafarin *et al.*, 2011) [57].

The crop prefers well-drained loam soils with a pH of 8-8.5 (Basu *et al.*, 2016) [15]. To optimise fenugreek seed development potential while boosting soil biodiversity, it must be incubated with an appropriate *Rhizobium inoculum* (Acharya *et al.*, 2006) [2]. Under saline soil conditions, there is evidence that wheat straw and various fungal strains (*Sinorhizobium meliloti*, *Trichoderma harzianum*, *Aspergillus*

*niger*, and *Chaetonium globosum*) can promote nodulation, nodule efficiency, and Fenugreek growth (Acharya *et al.*, 2006) [2]. Farmyard manure, sewage, and/or kitchen waste compost are among the organic and inorganic fertilisers that fenugreek responds well to (Basu *et al.*, 2016) [15].

## 2.1 Growing period of fenugreek

The time takes for seeds to germinate in soil varies from 3 to 10 days (Mehrafarin *et al.*, 2011) [57]. The seedlings produce the first leaf, which is usually six to ten days after germination. There is still no visible epicotyl as the first trifoliate leaf is formed after another 5 – 8 days (Branch *et al.*, 2013) [13]. Fenugreek's growth rate is constant at the start of the growing season, and leaf development is temperature-dependent (Gurdas *et al.*, 2020) [30].

## 2.2 Ecology

Although the major region cultivated with fenugreek is centred in Asian and African countries, it has been disseminated in many countries throughout the world under various environmental conditions (Branch, 2013) [13]. This extensive distribution of fenugreek cultivation around the world is due to its ability to adapt to a variety of climatic and growth conditions (Akinrinde and Olanite, 2014) [3]. Fenugreek can withstand annual precipitation of 3.8–15.3 dm and annual temperature varying between 7.8–27.5 °C (Mehrafarin *et al.*, 2011) [57]. Sapogenin concentration, measured as diosgenin, ranged from 0.8–2.2 percent on a moisture-free basis, depending on the seed's geographical origin (Skaltsa, 2002) [79].

**Table 1:** Some ecological factors of fenugreek growth

Factors	Significant findings/report	Reference
Climate	<ul style="list-style-type: none"> <li>• Temperate climate with mild winters and cool summers.</li> <li>• Moderate or low rainfall.</li> <li>• It is fairly drought resistant and fairly frost sensitive.</li> <li>• It can tolerate 10 °C-15 °C of frost.</li> </ul>	Mehrafarin <i>et al.</i> (2011) [57] McCormick <i>et al.</i> (2009) Akinrinde <i>et al.</i> (2014) [3]
Altitude	<ul style="list-style-type: none"> <li>• Up to 1300 - 1400 m above sea level.</li> </ul>	Kumar (2019) [50]
Soil	<ul style="list-style-type: none"> <li>• Well-drained loams and slightly alkaline soils are suitable but in some severely acidic conditions, lime application may be required.</li> <li>• Heavy and wet soils limit fenugreek growth.</li> <li>• Optimum pH for the growth is reported to be 8-8.5.</li> </ul>	Mehrafarin <i>et al.</i> (2011) [57] Acharya <i>et al.</i> (2006) [2] Basu <i>et al.</i> (2016) [10]

## 3. Nutraceutical Properties of Fenugreek seeds

Fenugreek is considered as a medicinal herb both in Indian Ayurvedic and traditional Chinese medicines (Acharya *et al.*, 2006) [2]. Till now, hundreds of phytochemicals have been isolated and identified from fenugreek seeds, including polysaccharides, saponins, alkaloids, polyphenols, and flavonoids (Khole *et al.*, 2014) [48]. Fenugreek seeds mainly contain many important chemical constituents with medicinal value, *viz*; steroidal sapogenins, galactomannans and isoleucine and these constituents seem to work in a synergistic way to produce health benefits making fenugreek is one of the most well-known "nutraceutical" or "health food" items (Acharya *et al.*, 2006) [2]. Moreover, it also contains alkaloids, which mainly constitute of trigonelline (0.2–0.38%), diosgenin (0.6–1.7%) and yamogenin-based saponins (4.8%), 4- hydroxyisoleucine (0.09%), volatile oil (1.25%) and C-glycosylflavones of apigenin and luteolin (0.10%) (Khole *et al.*, 2014) [48]. Fenugreek seeds were earlier used to ease childbirth and to increase milk flow and it is still

traditionally used as a remedy for various ailments, for instance it is taken by women for menstrual pain and to ease stomach problems. They are also used for the treatment of indigestion, flatulence and a sluggish liver (Olaiya and Soetan, 2014) [62]. Several clinical trials suggested that fenugreek seeds can improve most of the metabolic symptoms associated with diabetes mellitus in humans by lowering blood glucose levels and improving insulin sensitivity (Hannan *et al.*, 2007) [35]. Fenugreek seeds exhibit antioxidant activity due to the presence of flavonoids and polyphenols (Dixit *et al.*, 2005) [21]. It also has been reported to show protective effects against hydrogen peroxide-induced oxidation by preventing the erythrocytes from haemolysis and lipid peroxidation (Kaviarasan *et al.*, 2004) [39]. Fenugreek seeds can be advised and made a part of our regular diet based on their nutraceutical features, as their liberal usage is safe and can provide a variety of health benefits (Fatima *et al.*, 2018) [25].

**Table 2:** Nutritive value of fenugreek leaves and seeds

Nutrient	Nutritive value of fenugreek seeds per 100 g	Nutritive value of fenugreek leaves per 100 g	References
Energy	323 kcal	49 kcal	Dwivedi <i>et al.</i> (2019); Navale <i>et al.</i> (2014) [24]
Protein	364.00 g	4.4g	White lupine (2012); Acharya <i>et al.</i> (2006) [65, 2]
Carbohydrates	42.3 g	6g	Meghwal and Goswami (2012); Navale <i>et al.</i> (2014) [56]
Fat	7.5 g	0.83g	Sheikhlar (2013); Longvah <i>et al.</i> (2017) [75, 52]
Dietary fiber	47.55 g	4.90g	Longvah <i>et al.</i> (2017) [52]
Calcium	1.76 mg	3.95 mg	Khorshidian <i>et al.</i> (2016); Gharneh, Davodalhosseini (2015) [44, 31]
Iron	335.0 mg	165.0 mg	Khorshidian <i>et al.</i> (2016); Gharneh, Davodalhosseini (2015) [44, 31]
Niacin	1.640 mg	0.70mg	Khadr, Fattah (2006); Longvah <i>et al.</i> (2017) [49, 52]
Magnesium	1.91 mg	0.67mg	Khorshidian <i>et al.</i> (2016); Gharneh, Davodalhosseini (2015) [44, 31]
Sodium	40.20 mg	0.76 mg	Longvah <i>et al.</i> (2017), Gharneh, Davodalhosseini (2015) [52, 31]
Vitamin A	1210 µg	12755 µg	Longvah <i>et al.</i> (2017) [17]
Vitamin C	3 mg	1.3 mg	Fezea (2015); Bishnoi <i>et al.</i> (2020) [26, 18]
Phosphorus	370 mg	51 mg	Gopalan <i>et al.</i> (1971) [32]
Potassium	891 mg	0.31 mg	Longvah <i>et al.</i> (2017), Gharneh, Davodalhosseini (2015) [52, 31]
Copper	1.16 mg	2.60 mg	Longvah <i>et al.</i> (2017), Gharneh, Davodalhosseini (2015) [52, 31]
Thiamine	1.2 mg	0.11mg	Qureshi and Banday (2015) [67]
Riboflavin	0.366 mg	0.22mg	Sheikhlar <i>et al.</i> (2018); Longvah <i>et al.</i> (2017) [18, 17]
Folate	57 µg	75.26 µg	Doshi <i>et al.</i> (2012); Longvah <i>et al.</i> (2017) [23, 52]

#### 4. Bioactive properties of fenugreek seeds

##### 4.1 Hypocholesterolemic effect

Dietary fiber decrease blood glucose levels and reduce serum lipids (Yamashita *et al.*, 1984) [91]. The defatted portion of fenugreek seed induced hypocholesterolaemic effect (Valette *et al.*, 1984). Fenugreek extract has been investigated for its effects on blood lipid in rats with diabetics and the rats treated with fenugreek extract had lower triglycerides, total cholesterol and higher HDL (Xue *et al.*, 2007). Fenugreek seeds consist large amount of fiber in which galactose and mannose are the main composition of its gum. These compounds showed effect of reducing cholesterolemia (Roberts, 2011).

##### 4.2 Anti-Cancerous properties

Fenugreek seeds have a wide spread use in traditional Indian medicine for the treatment of hypercholesterolemia and hypertriglyceridemia, however, it have received little attention as an agent in the treatment of cancer (Tripti and alka 2020). Anticarcinogenic activity of fenugreek seeds is a promising protective medicinal herb for complementary therapy in cancer patients under chemotherapeutic interventions because fenugreek extract shows a protective effect by modifying the cyclophosphamide induced apoptosis and free radical-mediated lipid peroxidation in the urinary bladder of mice (Oliya *et al.*, 2014) [62]. Diosgenin present in fenugreek has also been reported to prevent cell growth and induce apoptosis in the H-29 human colon cancer cell line (Raju and Bird, 2006). In addition, it has also been found to have hepatoprotective properties and polyphenolic extract of fenugreek seed has been reported to acts as a protective agent against ethanol induced abnormalities in the liver (Kaviarasan and Anuradha, 2007) [41]. It was seen that fenugreek seeds has anticancer properties against MCF-7 human immortalised breast cells due to induction of apoptosis and increasing the expression of pro-apoptotic genes (Khoja *et al.*, 2011) [45]. The seeds of fenugreek has also shown proliferative inhibition on MCF-7 breast cancer cell line at a concentration of 400 µg/mL after 72 h of incubation, which showed that the herb could be a potent anticancer agent (Timimi, 2019) [6].

##### 4.3 Antioxidant properties

Fenugreek seed can be of benefit to human health. The *Trigonella foenum-graecum* seed is used in traditional Indian and Chinese medicinal for the treatment of diabetes, fever, as a poultice for abscesses, boils and its wound healing. (Kenny *et al.*, 2013) [47]. Phenolic and flavonoid compounds present in fenugreek seeds enhance its antioxidant capacity. Due to these bio-active compounds in the fenugreek seeds it has powerful antioxidant property that has beneficial effect on liver and pancreas (Olaiya *et al.*, 2014) [62]. Since antioxidant properties of these seeds have been linked to various health benefits; but properties of germinated fenugreek seeds were observed to be more beneficial than dried seeds because of the fact that germinated seed increases the bioavailability of different constituents of fenugreek (Dixit *et al.*, 2005) [21]. Furthermore, the presence of antioxidant carotenoid in fenugreek seeds showed hypoglycemic and anti-hyperglycemic effects in diabetic mice (Aruna *et al.*, 2010) [4].

##### 4.4 Anti-inflammatory properties

*Trigonella foenum-graecum* plant is widely distributed all over the world (Snehlata *et al.*, 2012) [83]. The plant contains active phytochemicals such as alkaloids, flavonoids, steroids, Saponins etc. (Snehlata *et al.*, 2012) [83]. Fenugreek seeds are also known for their anti-inflammatory effects. (Mashkor, 2014) [58]. A study conducted to determine the anti-inflammatory activity of fenugreek seed petroleum ether extract (FSPEE) indicates that, after treatment with FSPEE in rats, the inflammation in paw of the carrageenan reduced by 37% and in formaldehyde-induced paw edema, the inflammation reduced by 85% (Pundarikakshudu *et al.*, 2016) [66]. Fenugreek has high potential as antiinflammatory agent when formulated as emulsifying ointment for treating acute inflammatory disorders (Jyothi, 2014) [38].

##### 4.5 Hypoglycemic properties

Fenugreek seeds are known for their anti-diabetic action since long time as it contain high amount of fiber, soluble fiber (30%) and insoluble fiber (20%), it lowers blood glucose level

due to its high content of soluble fiber which would delay the gastric emptying and interfere with glucose absorption (Bawadi *et al.*, 2009) <sup>[17]</sup>. Dietary fiber has the effect to enhance peripheral insulin sensitivity and blood lipid therefore playing an important role in the treatment of diabetes (Timm and Slavin, 2008) <sup>[84]</sup>. Like insulin, fenugreek seeds also induce phosphorylation of the insulin tyrosine kinase receptor in adipocytes and liver cells (Saadh and Mohamed, 2020) <sup>[82]</sup>. Significant mean improvements in fasting blood glucose levels and glucose-tolerance test results were described in the fenugreek-treated patients (Smith and Micheal, 2003) <sup>[81]</sup>. Some studies also suggest that fenugreek seed extract with diet and exercise may be equally effective for attaining glycemic control in diabetic patients (Smith and Micheal, 2003) <sup>[81]</sup>. The anti-diabetic effect of fenugreek seeds is also thought to be due to formation of a colloidal-type suspension in the stomach and intestines when the mucilaginous fiber of the seeds is hydrated, therefore affecting gastrointestinal emptying, and slowing glucose absorption (Al-Asadi, 2014) <sup>[9]</sup>. It has also been found to lower the levels of fasting serum glucose, both acutely and chronically (Smith and Micheal, 2003) <sup>[81]</sup>. Moreover, the antioxidant activity of fenugreek seeds has been reported through the significant decrease in lipid peroxide level, which exerts health promoting effects on the increased oxidative stress in diabetic patients (Saadh and Mohamed, 2020) <sup>[82]</sup>. Apart from biochemical improvements in diabetes, fenugreek seeds have been reported to markedly suppress the clinical symptoms of diabetes such as polyuria, polydipsy (Al-Asadi, 2014) <sup>[9]</sup>. However, researches today have shown that not just the fiber, but many components of the seeds are involved in this life changing effect. The components, such as 4-hydroxyisoleucine and galactomannan present in fenugreek seeds have shown insulinotropic properties and inhibition of glucose absorption respectively (Basu *et al.*, 2010) <sup>[12]</sup>. These constituents of the fenugreek are believed to act synergistically in inhibiting glucose absorption and promoting pancreatic functions (Basu *et al.*, 2010) <sup>[12]</sup>.

##### 5. Mechanism of effect of fenugreek seeds on blood glucose levels

Diabetes mellitus is a serious, health condition of high blood glucose levels. If it is left untreated, it may result in serious ailments like blindness, heart attacks, strokes, renal failure and amputations (Mayfield, 1998) <sup>[54]</sup>. Diabetes mellitus is a metabolic dysfunction resulting from a deformity in insulin production, insulin action, or both. Insulin deficiency in turn leads to chronic hyperglycaemia with disturbances of carbohydrate, lipids and protein metabolism (Bastaki, 2015) <sup>[16]</sup>. This chronic metabolic disorder diabetes mellitus is a rapidly growing global issue with huge social, health, and economic consequences (Kaul *et al.*, 2015) <sup>[43]</sup>. People with all forms of diabetes of ample duration, including insulin-dependent diabetes mellitus (IDDM) and noninsulin-dependent diabetes mellitus (NIDDM), are vulnerable to these complications, which cause serious morbidity (Nathan, 1993) <sup>[61]</sup>. A regular consumption of functional foods and herbal supplements may be associated with enhanced anti-oxidant, anti-inflammatory, insulin sensitivity, and anti-cholesterol functions, which are considered integral to prevent and

manage symptoms of diabetes mellitus (Alkhatib *et al.*, 2017) <sup>[10]</sup>.

Fenugreek (*Trigonella foenum-graecum*) dried seeds have a wide range of application as a flavoring agent and are good source of protein, fat, crude fiber, minerals and vitamins (Al-Asadi, 2014) <sup>[9]</sup>. The plant contains bio-active components such as alkaloids, flavonoids, steroids, saponins etc. and also it is rich in soluble fiber, which helps in lowering blood sugar by hindering assimilation and retention of carbohydrates (Shashikumar *et al.*, 2019) <sup>[78]</sup>. Fenugreek seeds are associated with controlling blood sugar by decreasing the rate of glucose absorption in the gut, improving the function of beta islet cells of the pancreas, promoting insulin sensitivity and improving glucose utilization within cells (Dilworth *et al.*, 2021) <sup>[22]</sup>.

Most fruits and vegetables contain insoluble fiber but fenugreek contained soluble fiber (Singhal *et al.*, 2014) <sup>[74]</sup>. It was reported that soluble fiber of fenugreek slower down the digestion and absorption of carbohydrate thus improving homeostasis of glucose (Hannan *et al.*, 2007) <sup>[35]</sup>. Soluble fiber had a beneficial effect on dyslipidemia and could inhibit platelet aggregation in Type 2 model diabetic rats (Hannan *et al.*, 2007) <sup>[35]</sup>. Almost 30% of fenugreek seed is gel-forming soluble fiber and 20% of insoluble fiber is bulk-forming like wheat bran (Phadnis *et al.*, 2011) <sup>[64]</sup>.

Galactomannan is a soluble dietary fiber compound of fenugreek, which lowers blood glucose levels in diabetic rats (Jiang *et al.*, 2017) <sup>[37]</sup>. Dietary fibers are indigestible complex carbohydrates found in plant foods serving as an essential ingredient in a healthy diet (Wang *et al.*, 2019) <sup>[87]</sup>. Researchers have also proven that adding 100g fenugreek powder containing 50% dietary fiber for a period of 10 days decreased 25% blood glucose level among the type II diabetes patients (Hammerness *et al.*, 2003) <sup>[34]</sup>. After 8 weeks of consumption of fenugreek seed by 40 patients in an experiment, urinary sugar and glycosylated hemoglobin were reported to reduce by 13% and 12.2%, (Khorshidian *et al.*, 2016) <sup>[44]</sup>.

Hypoglycemia is a condition of human body in which there is an abnormal decrease in the sugar level of the blood (Brun *et al.*, 2000). (Singh and Garg, 2006) <sup>[72]</sup> stated that fenugreek seeds have hypoglycemic and hypocholesterolemic effect after performing an experiment on animals. It also reported that fenugreek seeds improve peripheral glucose utilization improving glucose tolerance and exerts its hypoglycemic effect by acting at the insulin receptor level as well as at the gastrointestinal level (Meghwal and Goswami, 2012) <sup>[56]</sup>. Fenugreek seeds contain amino acid, 4hydroxyisoleucine, which can cause glucose-induced insulin release *in vitro* and *in vivo* (Rathore *et al.*, 2014) <sup>[68]</sup>. When diabetic rats with a dose of fenugreek during a 6-day period, glucose tolerance was greatly improved. The glycolytic enzymes show a decrease of activity in the liver, but an increase of activity in the kidney of diabetic rats (Kamalakkannan and prince, 2006) <sup>[42]</sup>. The activity of these glycolytic enzymes reached a controlled level, and there was a reduction of gluconeogenic enzyme activity (Kamalakkannan and prince, 2006) <sup>[42]</sup>. Fenugreek seeds can be advised and made a part of our daily diet based on these nutraceutical features because their liberal usage is safe and this natural herb can provide a variety of health benefits.

**Table 3:** Bioactive components of fenugreek seeds

Components	Description	References
Saponin	<ul style="list-style-type: none"> <li>Saponin played an important role in lipid and glucose balance.</li> <li>It also prevents fat deposition in adipocytes.</li> </ul>	Gupta <i>et al.</i> (2001) Kumar <i>et al.</i> (2013) [29, 13]
Trigonelline	<ul style="list-style-type: none"> <li>It shows improvement in the stress induced oxidation</li> <li>It shows antioxidant activities and is used as a potent source of antioxidants.</li> </ul>	Hamadi (2012) Dixit and Ghaskadbi (2005) [33, 21]
Polyphenol	<ul style="list-style-type: none"> <li>Dietary polyphenols may inhibit <math>\alpha</math>-amylase and <math>\alpha</math>glucosidase, inhibit glucose absorption in the intestine, hence showing anti-diabetic effect</li> <li>It regulates immunity by interfering with immune cell regulation, proinflammatory, synthesis of cytokines, and gene expression</li> </ul>	Kim <i>et al.</i> (2016) Yahfoufi <i>et al.</i> (2018) [46, 90]
Flavone Cglycosides	<ul style="list-style-type: none"> <li>It can inhibit digestive enzymes, activate insulin signaling, and reduce the formation of advanced glycation end products</li> </ul>	Xiao <i>et al.</i> (2016) [88]
4-Hydroxyisoleucine	<ul style="list-style-type: none"> <li>It has shown to cause an increase in glucose dependent insulin secretion.</li> <li>It also lower the elevated plasma triglycerides and total cholesterol levels.</li> </ul>	Jette <i>et al.</i> (2009) Narender <i>et al.</i> (2006) [36, 60]

## 6. Conclusion

Diabetes has been one of the most common diseases in people all over world. Since its prevalence increases yearly prevention and a cure has become one of the very important aspects. Present review study evaluated the nutritional and medicinal properties of fenugreek seeds such as antidiabetic, anti-carcinogenic, hypo-cholesterolemic, antioxidant and immunological activities. Fenugreek has a wide range of nutrients and bioactive substances that are necessary for biological systems to function properly. This review analyses the numerous health-promoting effects of fenugreek seeds based on their nutraceutical qualities, particularly those that may help manage blood glucose levels. The hypoglycemic effects of fenugreek seeds in diabetic patients are the subject of this research. For the same reason, a phyto-medicine such as fenugreek seeds, which can treat diabetes in its early stages while having fewer side effects and being less expensive, will be of great benefit to diabetic patients, especially given the widespread belief that natural treatments are less harmful to the body.

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## 8. References

- Aasim M, Baloch FS, Nadeem MA, Bakhsh A, Sameeullah M, Day S. Fenugreek (*Trigonella foenum-graecum* L.): An underutilized edible plant of modern world. In Global perspectives on underutilized crops Springer, Cham, 2018, 381-408.
- Acharya SN, Thomas JE, Basu SK. Fenugreek: an old world crop for the new world. Biodiversity. 2006 Dec 1;7(3-4):27-30.
- Acharya SN, Blade S, Mir Z, Moyer JR. Tristar fenugreek. Canadian Journal of Plant Science. 2007 Oct 1;87(4):901-3.
- Aruna G, Baskaran V. Comparative study on the levels of carotenoids lutein, zeaxanthin and  $\beta$ -carotene in Indian spices of nutritional and medicinal importance. Food chemistry. 2010 Nov 15;123(2):404-9.
- Akinrinde EA, Olanite JA. Fenugreek (*Trigonella foenum-graecum* L.) A Potential, All-Season, Forage Resource for Improved Ruminant Nutrition in Nigeria. American Journal of Social Issues and Humanities, 2014.
- Al-Timimi LA. Antibacterial and anticancer activities of fenugreek seed extract. Asian Pacific Journal of Cancer Prevention: APJCP. 2019;20(12):3771.
- Aishwath OP, Meena RD, Dubey PN. Role of micronutrients on morphophysiological and nutritional parameters including disease suppression of fenugreek 1. International Journal of Seed Spices. 2018 Jul;8:24-31.
- Aher RR, Belge SA, Kadam SR, Kharade SS, Misal AV, Yeole PT. Therapeutic importance of fenugreek (*Trigonella foenum-graecum* L.). A review. J Plant Sci Res. 2016;3(1):149.
- Al-Asadi JN. Therapeutic uses of fenugreek (*Trigonella foenum-graecum* L.). Am. J Soc. Issues Hum. 2014 Mar;2:21-36.
- Alkhatib A, Tsang C, Tiss A, Bahorun T, Arefanian H, Barake R, Khadir A, Tuomilehto J. Functional foods and lifestyle approaches for diabetes prevention and management. Nutrients. 2017 Dec 1;9(12):1310.
- Ayub MA, Sidra Sarwar, Muhammad Asif Hanif, Muhammad Adnan Ayub 2, Yaw Duah Boakye 3, Christian Agyare 3. medicinal plants of south Asia, 2019 Sep 14, 257.
- Basu TK, Srichamroen A. Health Benefits of Fenugreek (*Trigonella foenum-graecum* leguminosae). In Bioactive foods in promoting health 2010 Jan 1, 425-435. Academic Press.
- Branch S. Fenugreek (*Trigonella foenum-graecum* L.) as a valuable medicinal plant. International Journal of Advanced Biological and Biomedical Research. 2013;1:922-31.
- Basu SK. Seed production technology for fenugreek (*Trigonella foenum-graecum* L.) in the Canadian prairies Doctoral dissertation, Lethbridge, Alta.: University of Lethbridge, Faculty of Arts and Science, 2006.
- Basu SK, Cetzal-IX W, Zandi P. Forage fenugreek (*Trigonella foenum-graecum* L.) production: a boon for semi-arid agricultural regions. In VII international scientific agriculture symposium, Agrosym, 2016, 6-9.
- Bastaki S. Pharmacotherapy of nonnutritive sweeteners in diabetes mellitus. Int J Diabetes Metab. 2015;23:11-22.
- Bawadi HA, Maghaydah SN, Tayyem RF, Tayyem RF. The postprandial hypoglycemic activity of fenugreek seed and seeds' extract in type 2 diabetics: A pilot study. Pharmacognosy Magazine. 2009 Apr 1;5(18):134.
- Bishnoi S, Chhikara N, Singhania N, Ray AB. Effect of cabinet drying on nutritional quality and drying kinetics of fenugreek leaves (*Trigonella foenum-graecum* L.). Journal of Agriculture and Food Research. 2020 Dec 1;2:100072.
- Brun JF, Fédou C, Mercier J. Postprandial reactive

- hypoglycemia. *Diabetes and metabolism*. 2000 Nov 1;26(5):337-52.
20. Borchardt JK. The beginnings of drug therapy: ancient Egyptian medicine. *Drugs News Perspectives*. 1999 Mar 1;12:123-7.
  21. Dixit P, Ghaskadbi S, Mohan H, Devasagayam TP. Antioxidant properties of germinated fenugreek seeds. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*. 2005 Nov;19(11):977-83.
  22. Dilworth L, Facey A, Omoruyi F. Diabetes mellitus and its metabolic complications: the role of adipose tissues. *International Journal of Molecular Sciences*. 2021 Jul 16;22(14):7644.
  23. Doshi M, Mirza A, Umarji B, Karambelkar R. Effect of *Trigonella foenum-graecum* (fenugreek/methi) on hemoglobin levels in females of child bearing age. *Biomed Res*. 2012 Jan 1;23(1):47e50.
  24. Dwivedi YK, Rana NP, Jeyaraj A, Clement M, Williams MD. Re-examining the unified theory of acceptance and use of technology (UTAUT): Towards a revised theoretical model. *Information Systems Frontiers*. 2019 Jun;21(3):719-34.
  25. Fatima T, Maqbool K, Hussain SZ. Potential health benefits of fenugreek. *Journal of Medicinal Plants Studies*. 2018;6(2):166-9.
  26. Fezea FA, Norziah MH, Bhat R, Ahmad M. Effect of extraction solvents on antioxidant and antimicrobial properties of fenugreek seeds (*Trigonella foenum-graecum* L.).
  27. Garg RC. Fenugreek: multiple health benefits. In *Nutraceuticals Academic Press*. 2016 Jan 1, 599-617.
  28. Ghosh B, Chandra I, Chatterjee S. Fenugreek (*Trigonella foenum-graecum* L.) and its necessity. *Fire J. Eng. Technol*. 2015;1(1):66-7.
  29. Gupta A, Gupta R, Lal B. Effect of *Trigonella foenum-graecum* (Fenugreek) seeds on glycaemic control and insulin resistance in type 2 diabetes. *J Assoc Physicians India*. 2001;49:1057-61.
  30. Gurdas S, Patil RK, Diksha J, Patil HC. To evaluate growth factors of Fenugreek in hydroponic system and soil based system. *Int. J. Res. Anal. Rev*. 2020;7:265-9.
  31. Gharneh HA, Davodalhosseini S. Evaluation of Mineral Content in some Native Iranian Fenugreek (*Trigonella foenum-graecum* L.) Genotypes. *Journal of Earth, Environment and Health Sciences*. 2015 Jan 1;1(1):38.
  32. Gopalan C, Rama Sastri BV, Balasubramanian SC. Nutritive value of Indian foods, 1971.
  33. Hamadi SA. Effect of trigonelline and ethanol extract of Iraqi Fenugreek seeds on oxidative stress in alloxan diabetic rabbits. *Journal of the Association of Arab Universities for Basic and Applied Sciences*. 2012 Oct 1;12(1):23-6.
  34. Hammerness P, Basch E, Ulbricht C, Barrette EP, Foppa I, Basch S. St. John's wort: A systematic review of adverse effects and drug interactions for the consultation psychiatrist. *Psychosomatics*. 2003;44(4):271-82.
  35. Hannan JM, Ali L, Rokeya B, Khaleque J, Akhter M, Flatt PR, *et al*. Soluble dietary fibre fraction of *Trigonella foenum-graecum* (fenugreek) seed improves glucose homeostasis in animal models of type 1 and type 2 diabetes by delaying carbohydrate digestion and absorption, and enhancing insulin action. *British Journal of Nutrition*. 2007 Mar;97(3):514-21.
  36. Jetté L, Harvey L, Eugeni K, Levens N. 4-Hydroxyisoleucine: A plant-derived treatment for metabolic syndrome. *Current opinion in investigational drugs (London, England: 2000)*. 2009 Apr 1;10(4):353-8.
  37. Jiang W, Gao L, Li P, Kan H, Qu J, Men L, *et al*. Metabonomics study of the therapeutic mechanism of fenugreek galactomannan on diabetic hyperglycemia in rats, by ultra-performance liquid chromatography coupled with quadrupole time-of-flight mass spectrometry. *Journal of Chromatography B*. 2017 Feb 15;1044:8-16.
  38. Jyothi D, Koland M. Investigation of anti-inflammatory activity of ointments containing fenugreek extract. *Asian Journal of Pharmaceutical and Clinical Research*, 2014 May 1, 66-9.
  39. Kaviarasan S, Vijayalakshmi K, Anuradha CV. Polyphenol-rich extract of fenugreek seeds protect erythrocytes from oxidative damage. *Plant Foods for Human Nutrition*. 2004 Oct;59(4):143-7.
  40. Kassaian N, Azadbakht L, Forghani B, Amini M. Effect of fenugreek seeds on blood glucose and lipid profiles in type 2 diabetic patients. *International Journal for Vitamin and Nutrition Research*. 2009 Jan 1;79(1):34-9.
  41. Kaviarasan S, Viswanathan P, Anuradha CV. Fenugreek seed (*Trigonella foenum graecum*) polyphenols inhibit ethanol-induced collagen and lipid accumulation in rat liver. *Cell biology and toxicology*. 2007 Nov;23(6):373-83.
  42. Kamalakkannan N, Prince PS. Antihyperglycaemic and antioxidant effect of rutin, a polyphenolic flavonoid, in streptozotocin-induced diabetic wistar rats. *Basic & clinical pharmacology & toxicology*. 2006 Jan;98(1):97-103.
  43. Kaul K, Apostolopoulou M, Roden M. Insulin resistance in type 1 diabetes mellitus. *Metabolism*. 2015 Dec 1;64(12):1629-39.
  44. Khorshidian N, Yousefi Asli M, Arab M, Adeli Mirzaie A, Mortazavian AM. Fenugreek: potential applications as a functional food and nutraceutical. *Nutrition and Food Sciences Research*. 2016 Feb 10;3(1):5-16.
  45. Khoja KK, Shaf G, Hasan TN, Syed NA, Al-Khalifa AS, Al-Assaf AH, *et al*. Fenugreek, a naturally occurring edible spice, kills MCF-7 human breast cancer cells via an apoptotic pathway. *Asian Pac J Cancer Prev*. 2011 Jan 1;12(12):3299-304.
  46. Kim Y, Keogh JB, Clifton PM. Polyphenols and glycemic control. *Nutrients*. 2016 Jan;8(1):17.
  47. Kenny O, Smyth TJ, Hewage CM, Brunton NP. Antioxidant properties and quantitative UPLC-MS analysis of phenolic compounds from extracts of fenugreek (*Trigonella foenum-graecum*) seeds and bitter melon (*Momordica charantia*) fruit. *Food chemistry*. 2013 Dec 15;141(4):4295-302.
  48. Khole S, Chatterjee S, Variyar P, Sharma A, Devasagayam TP, Ghaskadbi S. Bioactive constituents of germinated fenugreek seeds with strong antioxidant potential. *Journal of functional foods*. 2014 Jan 1;6:270-9.
  49. Khadr NA, Abdel-Fattah FA. Response of broiler chickens to diet containing black seed (*Nigella sativa* L.) as medical plant. *Benha Veterinary Medical Journal*. 2006;17(2):323-43.
  50. Kumar A. Fenugreek. *Sankalp Publication*, 2019 Sep 25.
  51. Kumar C, Kumar R, Nehar S. Phytochemical properties, total antioxidant status of acetone and methanol extract of

- Terminalia arjuna* Roxb. bark and its hypoglycemic effect on Type-II diabetic albino rats. *Journal of Pharmacognosy and Phytochemistry*. 2013 May 1;2(1).
52. Longvah T, Anantan I, Bhaskarachary K, Venkaiah K, Longvah T. *Indian food composition tables*. Hyderabad: National Institute of Nutrition, Indian Council of Medical Research; 2017 May.
  53. Mandal S, Deb Mandal M. Fenugreek (*Trigonella foenum-graecum* L.) oils. In *Essential oils in food preservation, flavor and safety* 2016 Jan 1, 421-429. Academic Press.
  54. Mayfield JA. Diagnosis and classification of diabetes mellitus: new criteria. *American family physician*. 1998 Oct 15;58(6):1355.
  55. Monk BJ, Poveda A, Vergote I, Raspagliesi F, Fujiwara K, Bae DS, Oaknin A, Ray-Coquard I, Provencher DM, Karlan BY, Lhommé C. Anti-angiopoietin therapy with trebananib for recurrent ovarian cancer (TRINOVA-1): a randomised, multicentre, double-blind, placebo-controlled phase 3 trial. *The lancet oncology*. 2014 Jul 1;15(8):799-808.
  56. Meghwal M, Goswami TK. Effect of moisture content on physical and textural properties of fenugreek seeds. *Food In: Global Science Books*. 2012;6(1):14-21.
  57. Mehrafarin A, Rezazadeh SH, Naghdi Badi H, Noormohammadi GH, Zand E, Qaderi A. A review on biology, cultivation and biotechnology of fenugreek (*Trigonella foenum-graecum* L.) as a valuable medicinal plant and multipurpose. *فصلنامه علمی پژوهشی گیاهان دارویی*. 2011 Mar 10;10(37):6-24.
  58. Mashkor IM. Phenolic content and antioxidant activity of fenugreek seeds extract. *International Journal of Pharmacognosy and Phytochemical Research*. 2014;6(4):841-4.
  59. Mandegary A, Pournamdari M, Sharififar F, Pournourmohammadi S, Fardiar R, Shooli S. Alkaloid and flavonoid rich fractions of fenugreek seeds (*Trigonella foenum-graecum* L.) with antinociceptive and anti-inflammatory effects. *Food and Chemical Toxicology*. 2012 Jul 1;50(7):2503-7.
  60. Narender T, Puri A, Khaliq T, Saxena R, Bhatia G, Chandra R. 4-Hydroxyisoleucine an unusual amino acid as antidiabetic and antihyperglycemic agent. *Bioorganic & medicinal chemistry letters*. 2006 Jan 15;16(2):293-6.
  61. Nathan DM. Long-term complications of diabetes mellitus. *New England journal of medicine*. 1993 Jun 10;328(23):1676-85.
  62. Olaiya CO, Soetan KO. A review of the health benefits of fenugreek (*Trigonella foenum-graecum* L.): Nutritional, Biochemical and pharmaceutical perspectives. *Am. J. Soc. Issues Humanit*. 2014 Mar;4:3-12.
  63. Petropoulos GA, editor. *Fenugreek: the genus Trigonella*. CRC Press, 2002, Aug 22.
  64. Phadnis M, Malhosia A, Singh SM, Malhosia A. Therapeutic effect of fenugreek seed on the patients suffering from diabetes mellitus type II. *Journal of Biology, Agriculture and Healthcare*. 2011;1(2):50-5.
  65. Podleśny J, Stochmal A, Podleśna A, Misiak LE. Effect of laser light treatment on some biochemical and physiological processes in seeds and seedlings of white lupine and faba bean. *Plant Growth Regulation*. 2012 Jul;67(3):227-33.
  66. Pundarikakshudu K, Shah DH, Panchal AH, Bhavsar GC. Anti-inflammatory activity of fenugreek (*Trigonella foenum-graecum* Linn) seed petroleum ether extract. *Indian journal of pharmacology*. 2016 Jul;48(4):441.
  67. Qureshi S, Banday MT, Adil S, Shakeel I, Munshi ZH. Effect of dandelion leaves and fenugreek seeds with or without enzyme addition on performance and blood biochemistry of broiler chicken and evaluation of their *in vitro* antibacterial activity. *Indian Journal of Animal Sciences*. 2015 Nov 1;85(11):1248-54.
  68. Rathore SS, Saxena SN, Kakani RK, Sharma LK, Singh B. Rapid and mass screening methods for 4-hydroxyisoleucine compounds in fenugreek seeds. *International J. Seed Spices*. 2014 Jan;4(1):93-4.
  69. Roberts KT. The potential of fenugreek (*Trigonella foenum-graecum*) as a functional food and nutraceutical and its effects on glycemia and lipidemia. *Journal of medicinal food*. 2011 Dec 1;14(12):1485-9.
  70. Salman MT, Qadeer F. *Pharmacological Actions and Therapeutic Potential of Trigonella foenum-graecum L. In Fenugreek, 2021, 523-537*. Springer, Singapore.
  71. Srinivasan K. Fenugreek (*Trigonella foenum-graecum*): A review of health beneficial physiological effects. *Food reviews international*. 2006 Jul 1;22(2):203-24.
  72. Singh V, Garg AN. Availability of essential trace elements in Indian cereals, vegetables and spices using INAA and the contribution of spices to daily dietary intake. *Food chemistry*. 2006 Jan 1;94(1):81-9.
  73. Singh KP, Nair B, Jain PK, Naidu AK, Paroha S. Variability in the nutraceutical properties of fenugreek (*Trigonella foenum-graecum* L.) seeds. *Revista Colombiana De Ciencias Hortícolas*. 2013 Dec;7(2):228-39.
  74. Singhal P, Kaushik G, Mathur P. Antidiabetic potential of commonly consumed legumes: a review. *Critical reviews in food science and nutrition*. 2014 Jan 1;54(5):655-72.
  75. Sheikhlar A. *Trigonella foenum-graecum* L. (Fenugreek) as a medicinal herb in animals growth and health. *Science international*. 2013;1(6):194-8.
  76. Syed QA, Rashid Z, Ahmad MH, Shukat R, Ishaq A, Muhammad N, et al. Nutritional and therapeutic properties of fenugreek (*Trigonella foenum-graecum*): A review. *International Journal of Food Properties*. 2020 Jan 1;23(1):1777-91.
  77. Sharara MS. Effect of germination and heat treatment on chemical composition and bioactive components of fenugreek seeds. *World Journal of Dairy & Food Sciences*. 2017;12(1):33-41.
  78. Shashikumar JN, Champawat PS, Mudgal VD, Jain SK. Role of fenugreek (*Trigonella foenum-graecum*) on in management of diabetes disease. *Journal of Pharmacognosy and Phytochemistry*. 2019;8(4):184-7.
  79. Skaltsa H. Chemical constituents. In *Fenugreek, 2002 Aug 22, 148-177*. CRC Press.
  80. Sheikhlar A, Goh YM, Ebrahimi M, Romano N, Webster CD, Alimon AR, et al. Replacement of dietary fishmeal for fenugreek seed meal on the growth, body composition, innate immunological responses and gene expression of hepatic insulin-like growth factors in African catfish (*Clarias gariepinus*). *Aquaculture Nutrition*. 2018 Dec;24(6):1718-28.
  81. Smith M. Therapeutic applications of fenugreek. *Alternative Medicine Review*. 2003;8(1):20-7.
  82. Saadh MJ. Hypoglycemic and hypolipidemic activity of combined milk thistle and fenugreek seeds in alloxan-

- induced diabetic albino rats. *Veterinary World*. 2020 Aug;13(8):1732.
83. Snehlata HS, Payal DR. Fenugreek (*Trigonella foenum-graecum* L.): An overview. *Int J Curr Pharm Rev Res*. 2012 Jan 1;2(4):169-87.
84. Timm DA, Slavin JL. Dietary fiber and the relationship to chronic diseases. *American Journal of Lifestyle Medicine*. 2008 May;2(3):233-40.
85. Verma T, Gupta A. Plant Based Anti-cancerous Superfoods, Boosting Immunity: A Coherent Critique. *Int. J Curr. Microbiol. App. Sci*. 2020;9(5):1886-94.
86. Valette G, Sauvaire Y, Baccou JC, Ribes G. Hypocholesterolaemic effect of fenugreek seeds in dogs. *Atherosclerosis*. 1984 Jan 1;50(1):105-11.
87. Wang M, Wichienchot S, He X, Fu X, Huang Q, Zhang B. *In vitro* colonic fermentation of dietary fibers: Fermentation rate, short-chain fatty acid production and changes in microbiota. *Trends in Food Science & Technology*. 2019 Jun 1;88:1-9.
88. Xiao J, Capanoglu E, Jassbi AR, Miron A. Advance on the flavonoid C-glycosides and health benefits. *Critical reviews in food science and nutrition*. 2016 Jul 29;56(sup1):S29-45.
89. Yadav SR, Biyani DM, Umekar MJ. *Trigonella foenum-graecum*: A herbal plant review. *World Journal of Pharmaceutical Research*. 2019 Sep 6;8(12):402-19.
90. Yahfoufi N, Alsadi N, Jambi M, Matar C. The immunomodulatory and anti-inflammatory role of polyphenols. *Nutrients*. 2018 Nov 2;10(11):1618.
91. Yamashita K, Kawai K, Itakura M. Effects of fructo-oligosaccharides on blood glucose and serum lipids in diabetic subjects. *Nutrition Research*. 1984 Nov 1;4(6):961-6.
92. Żuk-Gołaszewska K, Wierzbowska J. Fenugreek: productivity, nutritional value and uses. *J Elementol*. 2017 Sep 1;22(3):1067-80.