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REVIEW ARTICLE

Fenugreek: A review on its nutraceutical properties and utilization in various food products

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Fenugreek;
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Abstract Fenugreek (*Trigonella foenum-graecum*) is a legume and it has been used as a spice throughout the world to enhance the sensory quality of foods. It is known for its medicinal qualities such as antidiabetic, anticarcinogenic, hypocholesterolemic, antioxidant, and immunological activities. Beside its medicinal value, it is also used as a part of various food product developments as food stabilizer, adhesive, and emulsifying agent. More importantly it is used for the development of healthy and nutritious extruded and bakery product. The present paper reviews about nutraceutical properties of fenugreek and its utilization in various product developments.

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1. Introduction

Fenugreek (*Trigonella foenum graecum*) is an annual plant belongs to the family Leguminosae. It is the famous spices in human food. The seeds and green leaves of fenugreek are used in food as well as in medicinal application that is the old practice of human history. It has been used to increase the flavoring and color, and also modifies the texture of food materials. Seeds of fenugreek spice have medicinal properties such as hypocholesterolemic, lactation aid, antibacterial, gastric stimulant, for anorexia, antidiabetic agent, galactagogue, hepatoprotective effect and anticancer. These beneficial physiological effects including the antidiabetic and hypocholesterolemic effects of fenugreek are mainly attributable to the intrinsic dietary fiber constituent which have promising nutraceutical value (Srinivasan, 2006). It is well known for its fiber, gum, other chemical constituents and volatile contents. Dietary fiber of fenugreek seed is about 25% which changes the texture of food. These days it is used as food stabilizer, adhesive and emulsifying agent due to its high fiber, protein and gum content. The protein of fenugreek is found to be more soluble at alkaline pH (Meghwal and Goswami, 2012). Fenugreek is having beneficial influence on digestion and also has the ability to modify the food.

1.1. Phytochemistry

Fenugreek contains a number of chemical constituents including steroidal sapogenins. Diosgenin component has been found in the oily embryo of fenugreek. There are two furastanol glycosides, F-ring opened precursors of diosgenin that have been reported in fenugreek also as hederagin glycosides. Alkaloids such as trigocoumarin, nicotinic acid, trimethyl coumarin and trigonelline are present in stem. The mucilage is a standing out constituent of the seeds (Khare, 2004). There is about 28% mucilage; a volatile oil; 2 alkaloids such as trigonelline and Choline, 5% of a stronger-smelling, bitter fixed oil, 22% proteins and a yellow coloring substance are present in stem (Grieve, 1984). Fenugreek contains 23–26% protein, 6–7% fat and 58% carbohydrates of which about 25% is dietary fiber (US Department of Agriculture, 2012). Fenugreek is also a rich source of iron, containing 33 mg/100 g dry weight (US Department of Agriculture, 2001).

1.1.1. Leaves

The leaves contain seven saponins, known as graecunins. These compounds are glycosides of diosgenin. Leaves contain about 86.1% moisture, 4.4% protein, 0.9% fat, 1.5% minerals,

1.1% fiber, and 6% carbohydrates. The mineral and vitamins present in leaves include calcium, zinc iron, phosphorous, riboflavin, carotene, thiamine, niacin and vitamin C (Rao, 2003). Yadav and Sehgal (1997) found that fresh leaves of fenugreek contain ascorbic acid of about 220.97 mg per 100 g of leaves and β -carotene is present about 19 mg/100 g. On the other side, it was reported that 84.94% and 83.79% ascorbic acid were reduced in sun and oven-dried fenugreek leaves respectively. Fresh leaves are used as vegetables in the diets. It was found that there was a better retention of nutrients in the leaves of fenugreek. The leaves of fenugreek should be stored in either in refrigeration conditions, or dried in oven, or blanched for sometime (about 5 min) and should be cooked in pressure cooker.

1.1.2. Seed

Fenugreek is known for its pleasantly bitter, slightly sweet seeds. The seeds are available in any form whether whole or ground form is used to flavor many foods mostly curry powders, teas and spice blend. Fenugreek seed has a central hard and yellow embryo which is surrounded by a corneous and comparatively large layer of white and semi-transparent endosperm (Betty, 2008). List of chemical constituents is shown in table below. The chemical composition of fenugreek (such as seeds, husk and cotyledons) showed that endosperm had the highest (4.63 g/100 g) saponin and (43.8 g/100 g) protein content. As against this, husk contains higher total polyphenols. The extracts of endosperm husk, and fenugreek seed at about 200 μ g concentration exhibited antioxidant activity 72%, 64%, and 56% respectively by free-radical scavenging method (Naidu et al., 2010).

The seeds of fenugreek contain about 0.1–0.9% of diosgenin and are extracted commercially. The structure of diosgenin is shown in Fig. 1. The plant tissue cultures from seeds of fenugreek when grown under optimal conditions have been found to produce as much as 2% diosgenin with smaller amounts of trigonin and gitongenin. Seeds also contain the saponin (fenugrin B). Fenugreek seeds have been found to contain several coumarin compounds as well as a number of alkaloids (e.g., trigonelline, gentianine, carpaine). The large amount of trigonelline is degraded to nicotinic acid and related pyridines during roasting (Acharya et al., 2006). The major bioactive compounds in fenugreek seeds are believed to be polyphenol compounds, such as rhaponticin and isovitexin (He et al., 2015) (Fig. 1).

Small amount of volatile oils and fixed oil has been found in fenugreek seeds (Sowmya and Rajyalakshmi, 1999). Blank et al. (1997) have found the odor active compounds based

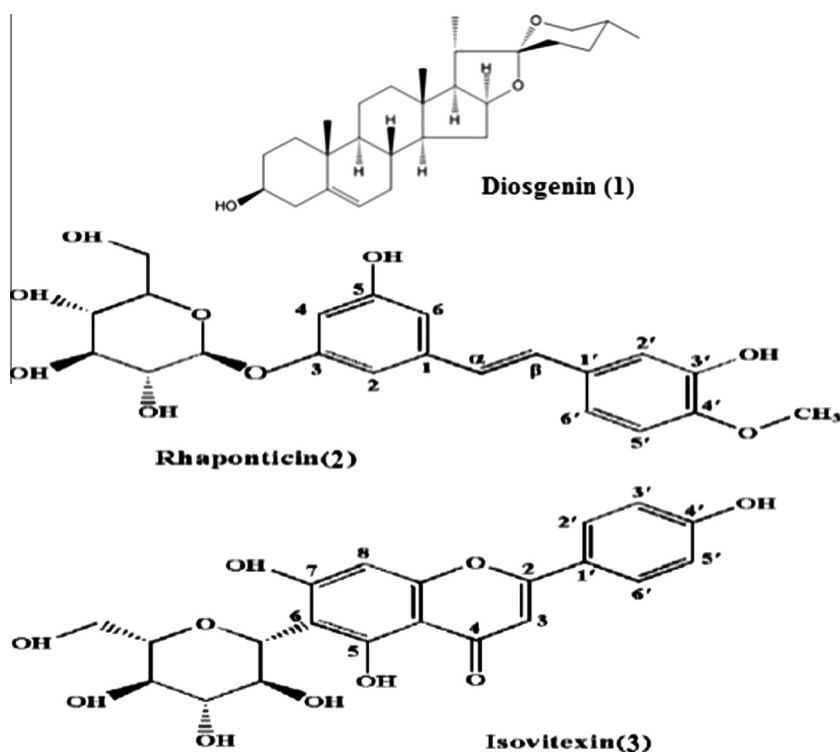


Figure 1 The chemical structures of (1) Diosgenin (2) rhaponticin and (3) isovitexin. *Volatile content.*

Table 1 Chemical constituents of fenugreek.

S. no.	Chemical constituents of fenugreek
Alkaloids	Trimethylamine, Neurin, Trigonelline, Choline, Gentianine, Carpaine and Betain
Amino acids	Isoleucine, 4-Hydroxyisoleucine, Histidine, Leucine, lysine, L-tryptophan, Arginine
Saponins	Graecunins, fenugrin B, fenugreekine, trigofenosides A–G
Steroidal saponogens	Yamogenin, diosgenin, smilagenin, sarsasapogenin, tigogenin, neotigogenin, gitogenin, neogitogenin, yuccagenin, saponaretin
Flavonoids	Quercetin, rutin, vitexin, isovitexin
Fibers	Gum, neutral detergent fiber
Lipids	Triacylglycerols, diacylglycerols, monoacylglycerols, phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol, free fatty acids. (Chatterjee et al., 2010)
Other	Coumarin, lipids, vitamins, minerals. 28% mucilage; 22% proteins; 5% of a stronger-swelling, bitter fixed oil.

Yadav et al. (2011), Sowmya and Rajyalakshmi (1999).

on the fenugreek aroma detection with the help of Gas Chromatograph and these includes the olfactometry diacetyl, 1-Octene-3-one, sotolon, acetic acid; 3-Isobutyl-2-methoxypyrazine, butanoic acid, isovaleric acid, 3-isopropyl-2-methoxypyrazine, caproic acid, eugenol, 3-Amino-4,5-dimethyl-3, linalool, (Z)-1,5-Octadiene-3-one, 4-dihydro-2 (5H)-Furanone with characteristic aroma of buttery like, roasty/earthy, metallic, pungent, paprika like, sweaty/rancid, flowery, musty, spicy respectively. Out of all these volatile

compounds, sotolon was reported to be found most predominantly in (5s)-enantiomeric form (95%) in fenugreek.

A study was conducted on sweat of human after fenugreek ingestion and it has been concluded that compounds responsible for the strong maple-syrup odor present in sweat after fenugreek ingestion are due to the following components including the following: pinene; 3-octen-2-one, 2,5-dimethylpyrazine, β -; camphor; terpinen-4-ol; 4-isopropyl-benzaldehyde; neryl acetate and β -caryophyllene but it was observed that 2,5-dimethylpyrazine to be a major component responsible for sweat odor contributing compound (Meghwal and Goswami, 2012). A list of chemical constituents is shown in Table 1 below.

1.2. Traditional uses

The medicinal value of fenugreek seeds is mentioned in Ayurvedic texts as well as in Greek and Latin pharmacopoeia. The Ayurvedic texts praise this herb for its power as an aphrodisiac, but modern vaidyas seem to be using it more for digestive and respiratory problems stemming from an excess of kaph (phlegm) and vat (wind). In ancient Egypt, methi was used to ease childbirth and to increase milk flow, and modern Egyptian women are still using it today to relieve menstrual cramps, as well as making hilba tea out of it to ease other kinds of abdominal pain. The Chinese call it hu lu ba, and also use it for treating abdominal pain. Though this cool season crop is grown in most corners of the world, its uses and people's awareness of its value vary considerably. In India, fresh methi ka saag (the stems and leaves of the plant) is very commonly cooked as a winter vegetable, and the seeds are used year-round as a flavoring agent for various dishes. The seeds are also eaten raw as sprouts and used medicinally. In Egypt

Table 2 Nutraceutical properties of fenugreek.

S. no.	Component used	Beneficial effects
1	Seeds	Hypoglycemic effect (Roberts, 2011)
2	Seeds	Hypocholesterolemic effect (Zia et al., 2001; Srivastava et al., 2012)
3	Seed, leaves	Antioxidant (Bukhari et al., 2008; Bhatia et al., 2006; Naidu et al., 2010)
6	Seed	Lactation aid (Snehlata and Payal, 2012; Al-Shaikh et al., 1999)
9	Seed	Immunomodulatory effect (Meghwal and Goswami, 2012)
10	Seed	Digestive effect (Platel and Srinivasan, 2000)
11	Seeds and leaves	Decreases blood pressure (Sowmya and Rajyalakshmi, 1999)
14	Seeds and leaves	Wounds and sore muscles treatment (Mathern et al., 2009)
15	Seeds, leaves	Anti-cancer agent (Sowmya and Rajyalakshmi, 1999; Mathern et al., 2009)
16	Seeds	Asthma, emphysema, pneumonia
17	Seeds leaves	Anti-ulcer agent
19	Seed	Induces growth and reproduction hormones (Blank, 1996)
20	Leaves and seeds	Gastro- and hepatoprotective (Blank, 1996)
21	Seed	For healthy heart (Blank, 1996)
23	Seed	Prevents constipation (Sowmya and Rajyalakshmi, 1999)
24	Seed, leaves	Digestive and appetizer (Sowmya and Rajyalakshmi, 1999)

and Ethiopia, methi is used in baking bread, and the Swiss use it for flavoring cheese. In the USA, it is mainly used to make spice blends for soups and stews (Passano, 1995).

The herb of fenugreek has been used for centuries as a cooking spice in European countries and it remains a popular ingredient in curry powders, pickles and spice mixtures in India Pakistan, Bangladesh and other Asian countries. Fenugreek has been used in the folk medicines for the treatment of cellulitis, boils, and tuberculosis. Fenugreek remained a key ingredient in a 19th century patent medicine for dysmenorrheal and postmenopausal symptoms. It also has been recommended for the promotion of lactation. The seeds of fenugreek have been used as an orally as insulin substitute for reduction in blood glucose, and the extracts from seed have been reported to lower blood glucose levels (Madar and Stark, 2002). The maple aroma and flavor of fenugreek have led to its use in imitation maple syrup.

2. Nutraceutical properties of Fenugreek

Fenugreek has a beneficial effect on cleansing the blood and as a diaphoretic it is able to bring on a sweat and to help detox the body. Due to pungent aroma of fenugreek, that is smelt on the skin and in under-arm perspiration. Fenugreek is also known for its lymphatic cleansing activity though its vital role is to irrigate the cells with nutrients and to remove toxic wastes, dead cells and trapped proteins from the body. Block in the lymphatic system can mean poor circulation of fluid, fluid retention, pain, energy loss and disease, anywhere in the body of a person. Fenugreek maintains mucus conditions of the body, mostly the lungs, by helping to clear congestion. It also acts as a throat cleanser

and mucus solvent that also eases the urge to cough. Drinking water in which seeds of fenugreek have soaked helps in softening and dissolving, accumulating and hardening the masses of cellular debris. Fenugreek has been used to relieve colds, bronchial complaints, influenza, asthma, catarrh, constipation, sinusitis, pleurisy, pneumonia, sore throat, laryngitis, hay fever tuberculosis and emphysema (Anon., 2013).

A list of nutraceutical properties of fenugreek is shown in Table 2.

2.1. Lactation aid

Breasts are modified sweat glands and fenugreek has been found to stimulate sweat production as it contains hormone precursor to increase milk formation. Some scientists reported that fenugreek can increase a nursing mother's milk supply within 24–72 h after first taking the herb (Snehlata and Payal, 2012).

Effect of Fenugreek seed on milk yield and fat percentage for 9 weeks in 21 lactating dairy goats was studied divided into three groups (A, B and C) according to the level of fenugreek in the feed (0%, 25% and 50% fenugreek, respectively). All diets were similar. Milk yield was recorded daily while fat percentage was determined weekly. The Group B showed significantly higher daily yield of milk and fat percentage than the other two groups, however group C showed a lower daily yield of milk and fat percentage than the control. Non-significant differences in plasma total protein, globulin, albumin, cholesterol, glucose and total lipids are found among the three groups (Al-Shaikh et al., 1999).

2.2. Immunological activity

An agent that intensifies or diminishes the immune responses is known as immunomodulator and such effect is called as immunomodulatory effect. A research work on the effect of fenugreek on stimulatory immunomodulatory effect (as evidenced from body weight, relative thymus weight, hemagglutination titer, quantitative hemolysis assay, phagocytosis, cellularity of lymphoid organs of body, late type of hypersensitivity response, plaque forming cell assay, a lymph proliferation and increase in phagocytic index and phagocytic capacity of macrophages significantly) of aqueous extract of fenugreek at three doses (50, 100 and 200 mg per kg) of body weight for ten days on the immune system of Swiss albino mice was studied (Meghwal and Goswami, 2012).

2.3. Hypoglycemic effect

Dietary fiber from fenugreek blunts glucose after a meal. The mechanisms for these effects have not been fully elucidated. Fenugreek seeds contain 45.4% dietary fiber (32% insoluble and 13.3% soluble), and the gum is composed of galactose and mannose. The latter compounds are associated with reduced glycemic effect. The hypoglycemic effect of fenugreek has been especially documented in humans and animals with type 1 and type 2 diabetes mellitus (Roberts, 2011).

Mechanism of action of an orally active hypoglycemic principle isolated from water extract of seeds of fenugreek was investigated in alloxan induced sub diabetic and overtly diabetic rabbits of different severity cases. Active component was orally administered to the subdiabetic and mild diabetic rabbits (five in

each group) at a dose of 50 mg per kg body weight for period of 15 days, and result showed significant attenuation of the glucose tolerance curve and improvement in the glucose induced insulin response. The result suggested that the hypoglycemic effect may be mediated through stimulating insulin synthesis and/or secretion from the beta pancreatic cells. Upon prolonged administration of the same dose of the active principle for 30 days to the severely diabetic rabbits lowered fasting blood glucose significantly, but could elevate the fasting serum insulin level to a much lower extent, which suggests an extra-pancreatic mode of action for the active principle. The effect may also be by increasing the sensitivity of tissues to available insulin. The hypoglycemic effect was observed to be slow but sustained, without any risk of developing severe hypoglycemia (Puri et al., 2002).

Impact of fenugreek incorporated therapeutic food on blood sugar levels of 24 non-insulin dependent diabetes mellitus patients was investigated in a study. A type of therapeutic food was developed from legumes viz., bengal gram, green gram, horse gram, dry peas and fenugreek seeds. An amount of 30 g of product was supplemented for a period of about one month and was found that both fasting and postprandial blood sugar levels were reduced significantly. So, it was concluded the usefulness of high fiber fenugreek diet in the management of diabetes (Kumari and Sinha, 2012).

The fenugreek extract has been investigated for its effects on blood glucose, hemorheological parameters and general properties in experimental rats having diabetics. The streptozotocin-induced rats (with diabetics) were administered by oral intragastric intubation separately with low dose, middle dose, high dose of fenugreek extract, and Metformin HCl for 6 weeks. Rats treated with fenugreek extract had an increase in body weight and a decrease in kidney/body weight ratio as compared with diabetic group. Rats treated with fenugreek extract had lower blood glucose, and glycated hemoglobin, in a dose-dependent manner as compared with diabetic group. It may be concluded that fenugreek extract can lower kidney/body weight ratio and blood glucose and also improves hemorheological properties in experimental diabetic rats following repeated treatment for 6 weeks (Xue et al., 2007).

The galactomannan-rich soluble fiber fraction of fenugreek seeds may be responsible for the antidiabetic activity. A study on animals evaluated the hypoglycemic effects of the fenugreek seeds on dogs. The seeds (defatted) lowered blood glucose levels, plasma glucagons and somatostatin levels; carbohydrate-induced hyperglycemia also was found to be reduced. Clinical analysis showed that glycemic control was improved in a small study of patients with mild type-2 diabetes mellitus. A reduction in glycosylated hemoglobin levels and increased insulin sensitivity were observed in fenugreek recipients (Snehata and Payal, 2012).

It is possible that fenugreek lowers lipids because it contains saponins that are transformed in the gastrointestinal tract into sapogenins. Fenugreek seeds contain 25% fiber that can slow the rate of postprandial glucose absorption. This may be a secondary mechanism for its hypoglycemic effect (Basch et al., 2003).

2.4. Hypocholesterolemic effect

The abnormal deficiency of cholesterol level in the blood is known as hypocholesterolemic problem and oral administration

of methanolic and aqueous extracts of seeds at a dose of one gram per kilogram body weight resulted in hypoglycemic effect in mice (Zia et al., 2001). Fenugreek seeds contain the large amount of fiber galactose and mannose are the main composition of gum. The latter compounds are associated with reduced cholesterolemia (Roberts, 2011).

The fenugreek extract has been investigated for its effects on blood lipid, and in experimental rats with diabetics. The streptozotocin-induced diabetic rats were administered by oral intragastric intubation separately with low dose, middle dose, and high dose of fenugreek extract, and Metformin HCl for about one and half month (6 weeks). As compared to diabetic group, rats treated with fenugreek extract had lower triglycerides, total cholesterol, and higher HDL cholesterol in a dose-dependent manner (Xue et al., 2007).

2.5. Antioxidant activity

Bukhari et al. (2008) reported that fenugreek seed extract with methanol, ethanol, dichloromethane, acetone, hexane and ethyl acetate has a radical scavenging activity. Bhatia et al. (2006) reported protective effect of fenugreek, on lipid peroxidation and on enzymatic antioxidants. Naidu et al. (2010) reported that the proximate composition of fenugreek seeds, husk and cotyledons had the highest saponin and protein content. In contrast, husk had higher total polyphenols. At 200 µg concentration, fenugreek seed, extracts of husk and endosperm exhibited 72%, 64%, and 56% antioxidant activities respectively by free-radical scavenging activity. From the study it was indicated that separation of fenugreek seeds into husk and endosperm could have advantage of process viability with respect to prior selective fractionation of bioactive components for their effective isolation. Laroubi et al. (2007) studied the prophylaxis effect of fenugreek seeds on renal stone formation in rats. The fenugreek can be used in the treatment of patients with calcic urolithiasis. Chauhan et al. (2010) reported an anti-inflammatory potential of fenugreek.

In a study it was observed that *Aegle marmelos* has the highest phenolic content followed by fenugreek and *Coriander sativum*; similarly the flavonoids contents are high in fenugreek followed by *C. sativum* and *A. marmelos*. Antioxidant property was checked by reducing power, NBT assay and H₂O₂ scavenging. *A. marmelos* showed the highest reducing power followed by *C. sativum* and fenugreek but fenugreek showed the highest superoxide and free radical scavenging followed by *C. sativum* and *A. marmelos* respectively (Joglekar et al., 2012).

2.6. Anticancer effect

Cancer is one of the leading causes of mortality all around the world. Many reported studies have shown the protective effect of fenugreek seeds in experimental models of cancer using cell lines or experimental animals. Amin et al. (2001) showed that fenugreek seed extract significantly inhibited 7,12-dimethyl benz(a)anthracene-induced mammary hyperplasia and reduces its incidence in rats and advised that the anti-breast cancer protective effects of fenugreek could be due to increased apoptosis. Further, alcoholic whole plant extracts of fenugreek showed in vitro cytotoxicity against different human cancer cell lines such as IMR-32, a neuroblastoma cell line, and HT29, a cancer cell line (Verma et al., 2010). A selective cytotoxic effect of

fenugreek extract in vitro to a panel of cancer cell lines has been observed, including T-cell lymphoma by [Alsemari et al. \(2014\)](#). [Sebastian and Thampan \(2007\)](#) examined the growth of MCF-7 cells, which is an estrogen receptor positive breast cancer cell line, with ethanol extracts of fenugreek, and reported that the ethanol extract of fenugreek decreased cell viability and induced early apoptotic changes such as inversion of phosphatidyl serine and decreased mitochondrial membrane potential. Further, degradation of DNA into fragments comprising multiples of approximately 180–200 base pair has also been observed. Cell cycle analysis revealed a sub-G1 apoptotic population along with cell cycle arrest at G2/M phase in fenugreek extract treated cells implicating the role of fenugreek extract-induced apoptosis in its anticancer role. According to the investigation made by [Shabbeer et al. \(2009\)](#), treatment with fenugreek extract showed growth inhibitory effects on breast, pancreatic and prostate cancer cell lines but primary prostate or immortalized prostate cells remained unaffected. Inhibition of cancer cell growth by *Trigonella* is attributed to its ability to induce death of cell, despite simultaneous upregulation of growth stimulatory pathways in normal cells. [Prabhu and Krishnamoorthy \(2010\)](#) also demonstrated anticancer activity of the ethanol extract of *trigonella* in Ehrlich Ascites Carcinoma cells induced cancer in Swiss albino mice. The mice inoculated with Ehrlich Ascites Carcinoma and treated with *trigonella* leaf extract showed increased life span in comparison with the tumor control, suggesting anticancer activity of fenugreek leaf extract in animal models.

A diet containing fenugreek seed powder decreased colon tumor incidence and hepatic lipid peroxidation in 1,2-dimethylhydrazine treated rats and also increased activities of catalase, superoxide dismutase, glutathione S-transferase and glutathione peroxidase in liver ([Devasena and Menon, 2007](#)). [Li et al. \(2010\)](#) showed that diosgenin could modulate the STAT3 signaling pathway in hepatocellular carcinoma by suppressing the activation of c-Src, JAK1 and JAK2. Diosgenin also down regulated the expression of various STAT3-regulated genes, inhibited proliferation and potentiated the apoptotic effects of paclitaxel and doxorubicin, suggesting that diosgenin could be a novel and potential treatment option for hepatocellular carcinoma and other cancers. Therefore, the role of fenugreek seed and its main active constituents as new supplements in diet-based preventive/therapeutic strategies to potentially alleviate human diseases remains an important field of study for future investigations ([Abdelgawad et al., 2012](#)).

2.7. Antibacterial and antifungal effect

The antibacterial and antifungal role of fenugreek is recently being shown. In a study by [Haouala et al. \(2008\)](#), an aqueous extracts from various plant parts of fenugreek in various solvents include methanol, petroleum ether and ethyl acetate fractions of the aerial parts and determine their action against fungal strains such as *Fusarium graminearum*, *Botrytis cinerea*, *Alternaria* sp., *Rhizoctonia solani* and *Pythium aphanidermatum*. It was found that all parts of the fenugreek plant showed antifungal potential and the magnitude of effect varies with plant parts and species of fungus. It could be suggested that fenugreek is an important source of biologically active compounds useful for developing better and novel antifungal drugs ([Haouala et al., 2008](#)). The effectiveness of extracts obtained from fenugreek against *Helicobacter pylori* has been reported by several studies ([O'Mahony et al., 2005](#); [Randhir et al.,](#)

Table 3 General uses of fenugreek.

S. no.	Component used	Utilization of fenugreek
1	Seeds	Bread (Isikli and Karababa, 2005 ; Thomas et al., 2011 ; Raju et al., 2001)
2	Fenugreek seeds, leaves	Biscuits (Hussein et al., 2011)
3	Seeds	Extruded product (Shirani and Ganesharane, 2009)
4	Fenugreek gum	Extruded products (Ravindran et al., 2011)
8	Seed, leaves	Culinary use (color, flavor, aroma) (Ramesh et al., 2001)
9	Leaves and seeds	Spice and seasoning (Sowmya and Rajyalakshmi, 1999 ; Srinivasan, 2005)
11	Seeds, leaves	Organoleptic character improver (Srinivasan, 2006)
12	Seed	Maple syrup and artificial flavoring (Blank, 1996)
14	Seed	(Mixed with flour for bread, yellow dye) food, (Srinivasan, 2006)
16	Seed	Dietary fiber, galactomannan (Blank, 1996)
17	Seed	Curries, condiments, pickles, chutneys as a flavoring (Madar and Stark, 2002)
20	Seed	Food stabilizer, adhesive and emulsifying agent (Jani et al., 2009 ; Sowmya and Rajyalakshmi, 1999)

[2004](#); [Randhir and Shetty, 2007](#)). In a study, honey samples with highest antibacterial activity against *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Escherichia coli* show maximum pollens from fenugreek than other plants ([Mercan et al., 2007](#)). Cysteine-rich peptides, defensins are small with potent antifungal activity. The methanol soluble fraction of fenugreek extract showed nematocidal activity and caused significant mortality of *Meloidogyne javanica* larvae, indicating the potential use against nematodes ([Zia et al., 2001](#)).

[Laroubi et al. \(2007\)](#) studied the prophylaxis effect of fenugreek seeds on renal stone formation in rats. The fenugreek can be used in the treatment of patients with calcic urolithiasis. [Chauhan et al. \(2010\)](#) reported an anti-inflammatory potential of fenugreek.

2.8. Advantages of fenugreek on digestion

Spices consumed in diet positively influenced the pancreatic digestive enzymes. [Platel and Srinivasan \(2000\)](#) experimentally showed that capsaicin, piperine, dietary curcumin, ginger, fenugreek and asafoetida prominently enhanced pancreatic lipase activity in rats, on feeding rats with spicy diets for eight weeks. Non-starchy polysaccharides increase the bulk of the food and increase the bowl movement. Also, non-starchy polysaccharides assist in smooth digestion whereas high fiber of fenugreek helps in relieving constipation ailments.

3. Utilization of fenugreek in various food products

A list of general uses of various parts of fenugreek in different food products is shown in [Table 3](#) below. Due to rich source of natural dietary fiber in fenugreek, it has established itself in the

modern food ingredient or functional food. Fenugreek as a hydrocolloid, which is fenugreek gum (soluble fiber of fenugreek), gives textural, appeal, thickening, emulsifying, stabilizing, gelling, and encapsulating properties. So the dietary fiber, more importantly soluble fiber can find their way into nutrition and dairy products, cereal bars, yogurts, and nutritional beverages. The powder of soluble fiber or total dietary fiber can be mixed with juices of fruit, seasonings and other spice mixes. Directly it can be used to formulate tablets or capsules along with the other vitamins and nutrients necessarily needed. It can also be used in milk shakes, dressings, soups, candies and sweets. It has been used to fortify bakery flour for pizza, pizza, cake mix, bread, bagel, muffins, flat bread, tortilla and noodles, fried, baked corn chips. Bakery foods such as bread, pizza, cakes and muffins have been prepared by using flour fortified with eight to ten percent soluble dietary fiber. When fiber fortified flour was used for making oil fried snacks, 8–15% of less oil absorption only takes place which is really appreciable in terms of unwanted fat intake (Im and Maliakel, 2008).

3.1. Fenugreek as food stabilizer, food adhesive, food emulsifier and gum

The interaction of fenugreek protein with the food constituents determines its ability to stabilize and emulsify the food constituents. Hefnawy and Ramadan (2011) evaluated the effect of fenugreek gum on solubility and emulsifying properties of soy protein isolate and they reported that the emulsifying activity of soy protein isolate with fenugreek gum was four times higher than that of soy protein isolate with fenugreek gum or fenugreek gum alone and the results were to those of bovine serum albumin. The emulsifying stability of soy protein isolate with fenugreek gum dispersions was respectively three times higher than that of soy protein isolate with fenugreek gum and bovine serum albumin. Emulsifying properties and solubility of soy protein isolate with fenugreek gum dispersions were also stable over wide ranges of high temperature, pH and ionic strength. Fenugreek contains higher dietary fiber content which acts as probiotic in functional food (Lee, 2009). Sowmya and Rajyalakshmi (1999) reported that the soluble fiber of fenugreek acts as an excellent substrate for fermentation done by the microorganisms in the large intestine.

The dietary fiber of fenugreek has potential for widespread use in the food industry because its galactomannan composition has emulsifying and stabilizing properties. Flour supplemented with a percentage of 8% and 10% of fenugreek dietary fiber has been used in the production of baked goods such as bread, pizza, muffins, and cakes. This application of fenugreek to flour allows for the production of functional foods that may be widely acceptable to consumers observing western diets (Roberts, 2011).

3.2. Fenugreek in traditional food

Fenugreek paste, locally termed as “Cemen” is a popular food in Turkey (Isikli and Karababa, 2005) which is prepared from ground fenugreek seeds. Crushed fenugreek seed or coarse fenugreek powder is used to make ball for making clarified butter.

3.3. Fenugreek in bakery products

Adding fenugreek fiber to refined flours helps to fortify with a balance of soluble and insoluble fiber. Flour fortified with 8–10% fenugreek fiber has been used to prepare bakery foods such as pizza, bread, muffins, and cakes with acceptable sensory properties (Srinivasan, 2005). Fenugreek seed husk is a rich source of dietary fiber and several important minerals. This fiber-rich functional ingredient can be incorporated in the manufacture of high-fiber muffins. The fiber-rich muffins possessed good volume, soft texture and medium-fine grain with twice the amount of DF (Srivastava et al., 2012). Losso et al. (2009) incorporated fenugreek in bread and demonstrated that fenugreek in food helps in reduction of blood sugar but due to its bitterness and strong odor its use is restricted. They did not find significant variation in color, texture, proximate composition, firmness, and flavor intensity between the wheat and fenugreek bread, but level of glucose and insulin was found to be lower in the fenugreek bread. Fenugreek's functional property of reducing insulin resistance was maintained in the bread. Therefore, it is evident from this study that fenugreek can be incorporated in baked products in acceptable limit which will reduce insulin resistance and treat diabetic patients as well.

Fenugreek flour has been incorporated up to a 10% level in the formulation of biscuits without affecting their overall quality. The physical, sensory and nutritional characteristics generally revealed that biscuits containing 10% germinated fenugreek flour were the best among all the composite fenugreek flour biscuits. Hence, development and utilization of such functional foods will not only improve the nutritional status of the general population but also helps those suffering from degenerative diseases (Hooda and Jood, 2005).

In a study incorporation of fenugreek flour up to 10% level has been used in the formulation of biscuits. Baking quality, color attributes and organoleptic evaluation revealed that wheat flour can be replaced using 10% Soaked Fenugreek and 20% Germinated Fenugreek flours to produce acceptable and high nutritional value biscuits. The study confirmed that fenugreek seed (raw, soaked and germinated) significantly reduced total lipids, serum total cholesterol, and LDL-cholesterol but non-significant changes in triglycerides and serum HDL-cholesterol were observed. It can be recommended that fenugreek may be used for lipid lowering purposes (Hussein et al., 2011). Supplementation of basal diets with fenugreek leaves, seeds (dry and germinated) and wheat flour supplemented with germinated fenugreek powder at 5–10% levels increased the total proteins, fibers, iron, zinc, calcium, vitamin B₂, carotene, vitamin E and vitamin C contents. These dietary supplements also improve the blood picture of anemic rats so they have nutritive and restorative properties. The daily use of fenugreek products as a dietary supplement is proved to be safe and healthy. Therefore, this study recommends that intake of fenugreek products may be beneficial for patients who suffer from iron deficiency anemia owing to their nutritive and restorative values (Nabila et al., 2012). In the same way 10% germinated fenugreek seed flour has been incorporated into the wheat based biscuits formula resulted in improving their chemical and nutritional quality and additionally also complimented the deficiency of lysine, isoleucine,

leucine, threonine and valine, and hence neutralizes the amino acid imbalance (Hegazy and Ibrahim, 2009).

3.4. Fenugreek in extruded product

Fenugreek seed flour and fenugreek leave powder have been used for the development of extruded snacks. In a study a mixture of about 1.78% fenugreek seed flour and 0.66% fenugreek leave powder with the base material was found to have high preference levels for parameters of physical, functional and color and could be extruded with acceptable quality characteristics (Wani and Kumar, 2015, 2016).

The effects of fenugreek flour and debittered fenugreek polysaccharide inclusion on the physical and sensory quality characteristics, and glycemic index (GI) of chickpea–rice based extruded products were studied. Due to the distinct bitter taste, inclusion of fenugreek flour was not acceptable at levels more than 2% in extruded chickpea based products. Addition of fenugreek polysaccharide resulted in slight reduction in radial expansion, while longitudinal expansion increased. Water absorption index increased while water solubility index decreased compared to the control. The mean scores of sensory evaluation indicated that all products containing fenugreek polysaccharide up to 15% were within the acceptable range. There were no significant differences between products containing 5–15% fenugreek polysaccharide in their color, flavor, texture and overall quality. Fenugreek, in the form of debittered polysaccharide could be incorporated up to a level of 15% in a chickpea–rice blend to develop snack products of acceptable physical and sensory properties with low Glycemic Index (Shirani and Ganesharane, 2009).

In another study fenugreek gum was extruded in a twin-screw extruder without an exit die to minimize a decrease in molecular weight of fenugreek gum during extrusion process. Both the steady and dynamic shear rheological tests revealed that extrusion process did not substantially influence the steady and dynamic shear properties of the gum. The power law model was applied to describe the flow behavior of the extruded gum solutions. The extrusion modified fenugreek gum solutions exhibited a shear thinning flow behavior at 25 °C, and the values of consistency index and apparent viscosity increased with an increase in the gum concentration. The magnitudes of storage modulus and loss modulus for the extrusion modified fenugreek gum solutions increased with increasing frequency and with increasing gum concentration (Chang et al., 2011). Fenugreek gum (extruded and non-extruded) was substituted for wheat flour at 0%, 5% and 10% (w/w) and the rheological effects and bread making characteristics were determined. Bread containing fenugreek gum (FG) at 5% and 10% showed volumes and texture comparable with control bread. Extruding FG also improved its solubility in bread. Fenugreek gum resulted in an increase in dough farinograph water absorption compared with the control, but extruding the gum caused an even greater increase in water absorption when compared with the non-extruded gum. The addition of FG to bread dough caused an increase in storage modulus (G') and loss modulus (G''). Starch pasting using RVA showed an increase in peak viscosity, final viscosity, breakdown and setback in a dose-related response when compared with a control (Roberts et al., 2012).

Another study showed the addition of fenugreek gum (FG) to the extruded pea–rice snack products. In addition to fenugreek gum, two more gums (guar gum and locust bean gum) were added to it. When these three gums were added to the formulations at levels of up to 20%, good expansion of the products occurred. The WAI of the extrudates containing FG increased with increasing inclusion levels. In addition to the high contents of starch that serve to provide energy, these snacks are good sources of protein and dietary fiber, and are low in fat, qualifying them as low Glycemic Index snack products. In particular, the reduction in Glycemic Index was the greatest with fenugreek gum extrudates (Ravindran et al., 2011).

4. Conclusions

Fenugreek having antidiabetic, antifertility, anticancer, antimicrobial, antiparasitic, lactation stimulant and hypcholesterolemic effects has been discussed in this review. Fenugreek has been found to have important bioactive compounds. From this review it was observed that fenugreek has been used as food stabilizer, food adhesive, food emulsifier and gum. Fenugreek has been used to produce various types of bakery products and extruded product. Based on these several health usefulness as discussed in review, based on various past reported scientific findings, fenugreek can be recommended and must be taken as a part of our daily diet as its liberal use is safe and various health benefits can be drawn from this natural herb. The above-mentioned studies on fenugreek suggest that the functional, nutritional and therapeutic characteristics of fenugreek can be exploited further in the development of healthy products.

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