Nutrition and Food Sciences Research Vol 3, No 1, Jan-Mar 2016, pages: 5-16

Review Article

Fenugreek: Potential Applications as a Functional Food and Nutraceutical

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Received: September 2015 **Accepted:** November 2015

ABSTRACT

Fenugreek (*Trigonella foenum graecum*), native to southern Europe and Asia, is an annual herb with white flowers and hard, yellowish brown and angular seeds, known from ancient times, for nutritional value beside of its medicinal effects. Fenugreek seeds are rich source of gum, fiber, alkaloids, flavonoids, saponins and volatile content. Due to its high content of fiber, fenugreek could be used as food stabilizer, adhesive and emulsifying agent to change food texture for some special purposes. Some evidence suggests that fenugreek may also be regarded as antidiabetic, anticarcinogenic, antioxidant, antibacterial agent, antianorexia agent, and gastric stimulant, as well as remedy for hypocholesterolemia and hypoglycemia. The present article is aimed to review the potential applications of fenugreek as a functional food and nutraceutical agent.

Keywords: Chemical composition, Fenugreek gum, Fenugreek, Health benefits

Introduction

Fenugreek (*Trigonella Foenum-gracium*) is a plant from the family of *Leguminosae* that grows annually, and is widely cultivated in the Mediterranean countries and Asia (Figure 1). The dried seeds have been traditionally used in India, China, Egypt and in some parts of the Europe for their beneficial health effects such as galactogouge, antibacterial, anti-inflammatory, insulinotropic, and rejuvenating properties (1). Pleasantly bitter and slightly sweet fenugreek seeds, which are available in whole and ground forms, are used as a source of flavoring for foods including curry powders, spice blends and teas. The seeds have horny and relatively large layer of white and semi-transparent endosperm encircling central hard, yellow embryo (2).

Wonderful functional and medicinal values of fenugreek are attributed to its chemical composition (20-25% protein, 45-50% dietary fiber, 20-25% mucilaginous soluble fiber, 6-8% fixed fatty acids and essential oils, and 2-5% steroidal saponins. Moreover, some minor components such as alkaloids (trigonolline, cholin, gentianine, carpaine, etc.), free unnatural amino acids (4- hydroxyisoleucine), and individual spirostanols and furastanols like diosgenin, gitogenin and yamogenin have also been identified and determined as the main components for its various biological effects (3)

Regarding the composition of fenugreek seeds (husk and cotyledons), it has been reported that their endosperm has the highest saponin (4.63 g/100 g) and protein (43.8 g/100 g) content, whereas husk has higher total polyphenols (103.8 mg of gallic acid equivalent/g, and total dietary fiber (TDF) (77.1 g/100 g), comprising of insoluble dietary fiber (IDF) (31.9 g/100 g) and soluble dietary fiber (SDF) (45.2 g/100 g). 200 µg extracts of husk, fenugreek seed, and endosperm showed 72%, 64%, and 56% antioxidant activity, respectively, by free-radical scavenging method (4). It has been shown that fenugreek has antidiabetic, anticancer, hypocholesterolemic, anti-

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inflammatory, antioxidant and chemo-preventive activity due to its useful chemical constituents. This review discusses nutraceutical properties, and potential food application of fenugreek which has not been reviewed anywhere before.

Fig1. Fenugreek plant and seed.

Chemical constituents of fenugreek seed

It was found that 100 g endosperm contains 43.8 g protein (4, 5). However, 100 g of fenugreek seed contained 25.4 g protein (6). Table 1 presents major proteins and amino acids in fenugreek seeds. Işıklı and Karababa (2005) reported that a high proportion of protein ranging from 20 to 30%, especially amino acid 4-hydroxyisoleucine, in fenugreek has high potential for insulin-stimulating activity (7). Fenugreek protein fraction is rich of lysine and can be compared with soybean protein (8). Youssef *et al.* (2009) indicated that residual proteins show a significant effect in decreasing the tension at the oil-water interface. The molecular weight of fenugreek gum is increased by removing the attached proteins, and by more increase in gum concentration or decrease in residual protein attached, the more increase in viscosity is resulted (9). El Nasri and El Tinay (2007) reported that emulsion and foaming properties of fenugreek proteins are greatly affected by pH levels and salt (NaCl) concentration. Both emulsion and foam properties are low at pH 4.5, which is the isoelectric point of the proteins. Moreover, they reported that fenugreek protein concentrate has high oil absorption capacity (1.56 ml oil per g protein), water absorption capacity (1.68 ml H_2O per g protein) and bulk density (0.66 g per ml). It was found that proteins of fenugreek seeds are more soluble in acidic (4.5) and alkaline (11) conditions than at nearly neutral pH (10). Srinivasan (2006) demonstrated that the quality of fenugreek seed proteins is not affected by cooking (11).

Vitamins and minerals: Although fenugreek is relatively low in mineral content, some minerals are present in good concentrations such as phosphorus and sulphur (10). It has also been reported that curry made from fenugreek has a high amount of calcium, iron and zinc (6). Table 1 provides an overview of vitamins and minerals and their levels in fenugreek seeds. Furthermore, germinating seeds have pyridoxine, cyanocobalamine, calcium pantothenate, biotin and vitamin C (12).

Srinivasan (2006) reported that fenugreek leaves contain vitamin C (52 mg per 100 g), β-carotene (2.3 mg per 100 g), thiamine (40 μg per 100 g), riboflavin (310 μg per 100 g), nicotinic acid (800 μg per 100 g) and folic acid (0 μm per 100 g), whereas these amounts for seed are 43 mg, 96 μg, 340 μg, 290 μg, 1.1 mg and 84 μg, respectively. There are nearly 10.8 and 7.4% loss of the vitamin by boiling in water, or steaming and frying, respectively, and exposure of the germinating seeds to *β*- and *γ*-radiation reduces the vitamin C content (11).

Fibers and gums: Fenugreek seeds are rich source of soluble dietary fiber (13). The 100 g of seeds provides more than 65% of dietary fiber, and contains saponins, hemicelluloses, mucilage, tannins and pectin, which help to decrease the level of low density lipoprotein-cholesterol (LDL) in the blood by decreasing the bile salts' re-absorption in the colon. Also it has been reported that fenugreek fiber binds to toxins in the food and helps to protect the colon mucus membrane from cancer toxins as well as lowering the rate of glucose absorption in the intestine, and thus controlling blood sugar levels. One of the major soluble fibers of the fenugreek seeds is galactomannan which decreases the bile salts' uptake in the intestine; it further reduces the digestion and absorption of starch in the body (14, 15). It has been reported that fenugreek husk is a remarkable source of dietary fiber and phenolic acids, which could be an effective source of natural antioxidants and natural ingredients in functional foods (4).

Table 1. **Chemical composition of fenugreek seeds**

Chemical composition	Nutrient value (per 100 g)
Protein & amino acids	
Globulin	-
Albumin	-
Lecithine	Totally 25.4 g
Histidine	-
lysine	-
4-hydroxyisoleucine	-
vitamines	
Vitamin A	1040 IU
Vitamin C	12 mg
Niacin	6 mg
Pyridoxine	0.6 mg
Thiamine	0.41 mg
Riboflavin	0.36 mg
Nicotinic acid	1.1 mg
Folate	57 µg
Minerals	
Calcium	176 mg
Iron	33.5 mg
Zinc	2.5 mg
Phosphorus	296 mg
Magnesium	191 mg
Manganese	1.22 mg
Selenium	6.3 µg

The main component in seed albumen is galactomannan (Figure 2) that is extracted from the endosperm of the seeds. Galactomannans are heterogeneous polysaccharides composed by a β-(1→4)-D-mannan backbone with a single D-galactose branch linked α-(1→6); they differ from each other by the mannose/galactose (M/G) ratio (16). Galactomannan has a property of increasing viscosity when dissolved in water. These properties make it an excellent ingredient for various food applications over the other natural hydrocolloids (17). Fenugreek galactomannan can be used as food stabilizer. Interfacial and surface tension reduction properties of fenugreek gum are comparable to those of Arabic gum.

Galactomannan in fenugreek can decrease surface tension even to levels lower than those of guar gum (42 and 55 mN/m, respectively).

Garti *et al*. (1997) indicated that fenugreek gum had an emulsifying capability for stabilizing oil-in-water emulsions, and the critical coverage of gum/oil ratio for stable non-coalesced emulsion was smaller than the one obtained for guar or other gums, implying its superior emulsification properties to those of other galactomannans. Due to better interfacial activity than other galactomannans, fenugreek gum can create oil-in-water emulsions with small droplet size (2–3 µm) and long-term stability. Fenugreek gum was found to adsorb (or 'precipitate') on the oil interface forming a relatively thick interfacial film (18).

Ramesh *et al*. (2001) showed that fenugreek galactomannan loses less of its crystal nature upon drying due to its regular structure, especially when galactose/mannose ratio is 0.93. Fenugreek gum has higher water solubility due to more galactose content in comparison to other types of gum like gaur gum (19). It has been reported that purified fenugreek gum containing 0.8% residual protein could reduce the surface tension and form stable emulsions with small oil droplets (2-3 µm) (18). Huang *et al*. (2001) also reported that crude fenugreek gum (13.9% protein) in comparison with 14 other hydrocolloid gums in a model system led to a very stable oil/water emulsion (20).

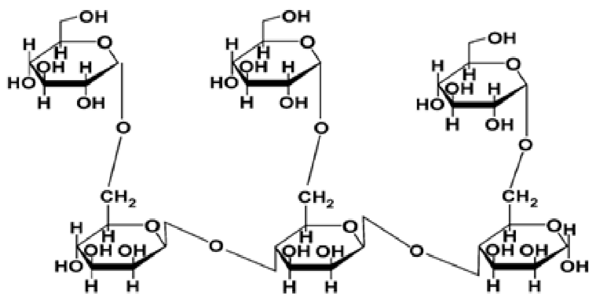

Fig 2. Fenugreek galactomannan structure.

Alkaloids, flavonoids and saponins: Fenugreek contains different alkaloids, flavonoids and saponins (21, 22); the latter is in the highest concentration (23). Alkaloid and volatile constituents of fenugreek seeds are the two major components, which cause bitter taste and bad odor (24). The level of flavonoid in fenugreek is more than 100 mg per g of seed (4). The main alkaloids, flavonoids and saponons are shown in Figure 3 (25-28). Benayad *et al.* (2014) investigated the phenolic compounds of fenugreek crude seeds from Morocco by HPLC–DAD–ESI/MS. Analysis showed that most of the identified compounds were acylated and non-acylated flavonoids with apigenin, luteolin and kaempferol as aglycons. The quantitative analysis of the identified compounds showed that the phenolic composition of the studied crude fenugreek seeds was predominantly acylated and non-acylated flavone derivatives with apigenin as the main aglycon (29). Alkaloids, flavonoids and saponins of fenugreek have pharmacological, antilipidemic, hypoglycaemic and cholagogic properties, and their use could manage diabetes mellitus and hypercholesterolemia due to lowering serum cholesterol level. Besides useful properties, they should be carefully taken to avoid minor gastrointestinal symptoms and allergic reactions (30).

Volatile compounds: Volatile oils in fenugreek are in small quantities (31). Girardon *et al*. (1985) identified 39 different compounds including *n*-alkanes, sesquiterpenes and some oxygenated compounds in the volatile oil of fenugreek seeds. The main components are *n*-hexanol, heptanoic acid, dihydroactiniolide, dihydrobenzofuran, tetradecane, *a*-muurolene, *b*-elemene and pentadecane. The dominant aroma component is a hemiterpenoid-γ-lactone, sotolon (3-hydroxy-4,5-dimethyl- 2(5*H*)-furanone), which is present in concentrations up to 25 ppm (32). Blank *et al*. (1997) also detected some odorous compounds in fenugreek seeds, as shown in Table 2 (33).

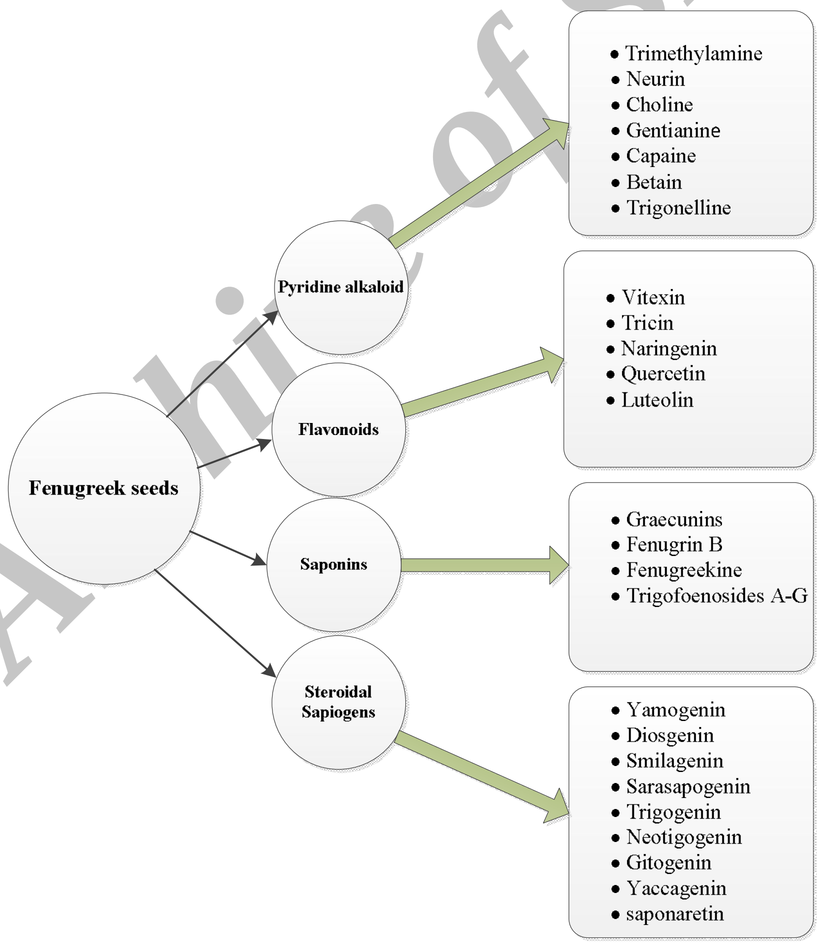

Fig 3. The main alkaloids, flavonoids, saponins and steroidal sapiogens in fenugreek seeds

Table2. Odorous compounds detected in aroma extract of fenugreek seeds

Odorous compound	Aroma quality
1-Octen-3-one	Mushroom-like
(*Z*)-1,5-Octadiene-3-one	Metallic
3-Isopropyl-2-methoxy pyrazine	Roasty, earthy
Acetic acid	Acidic, pungent
3-Isobuty-2-methoxy pyrazine	Roasty, paprika-like
Linalool	Flowery
Butanoic acid	Sweaty, rancid
Isovaleric acid	Sweaty, rancid
Caproic acid	Musty
Eugenol	Spicy
3-Amino-4,5-dimethyl 3, 4-dihydro-2-(5*H*) furanone	Seasoning-like
Stolon	Seasoning-like

Health and therapeutic benefits of fenugreek seed

Diabetes management: There are a significant number of works that have been carried out to show the efficacy of fiber, especially the soluble part of the fenugreek dietary fiber on blood and serum glucose management and insulin production. It was reported that adding 100 g of fenugreek powder containing 50 % dietary fiber for a period of 10 days decreased the blood glucose level by 25 %among the type II diabetes patients (34). It has been shown that soluble fiber fraction reduced postprandial elevation in the blood glucose level of type 2 diabetic rats by hindering the digestion of sucrose. Administering fenugreek soluble fiber orally twice daily at a dose of 0.5g/kg for 28 days resulted in reducing the serum fructosamine level with no significant change in the insulin level when compared with the control. It is concluded that soluble fiber had a beneficial effect on dyslipidemia, and that it could inhibit platelet aggregation in type 2 model diabetic rats (35). Moreover, it has been reported that soluble fiber of fenugreek postpones digestion and absorption of carbohydrates resulting in the improvement of glucose homeostasis (36). It could be explained by the extensive gel formation and low viscosity of the resulting gels inside the intestine, which may result in delaying the gastric emptying and decreasing the intestinal transit time of the food mass. Trapping the glucose inside the gel may leach out slowly and prevent the sudden rise of the blood glucose level. The viscous and gel-forming properties of soluble dietary fiber prevent macronutrient absorption, reduce postprandial glucose response, and beneficially affect certain blood lipids (37).

It is claimed that oral glucose tolerance in normal, type 1 or type 2 diabetic rats could be remarkably improved by administration of soluble dietary fiber (SDF) fraction. It is found that the amount of unabsorbed sucrose in the gastrointestinal tract of non-diabetic and type 2 diabetic rats was increased after oral consumption of sucrose.

Increment of blood glucose after oral sucrose ingestion was hindered by the SDF fraction in both non-diabetic and type 2 diabetic rats (36). Sharma *et al*. (1996) studied the effect of fenugreek seed powder on glycemia and insulinemia in 60, type 2 diabetes mellitus patients. Fenugreek seed powder (25g) was administered daily for 24 weeks. It resulted in blood glucose reduction after a glucose tolerance test as well as a reduction in basal blood glucose levels. Also, in an additional examination of 40 patients after 8 weeks of fenugreek seed consumption, the urinary sugar and glycosylated hemoglobin levels were significantly reduced by 13% and 12.2%, respectively (38). Srinivasan (2006) reported that consumption of 100 g defatted fenugreek seed powder daily for 10 days improved glucose tolerance and decreased fasting blood glucose levels in type 1 diabetic patients with a concomitant 50% reduction in urinary glucose excretion. There were significant hypoglycemic effects in the diabetic subjects when 10 g of the whole seed powder was consumed 3 hours before a glucose load whereas no effect was seen in the healthy subjects in the same conditions. It could be explained by the viscous properties of fenugreek causing the inhibition of glucose absorption from the small intestine. Srinivasan also stated that the hypoglycemic effects were highest in the whole seeds, followed by gum isolate, extracted seeds and cooked seeds, and the leaves had the weakest effect (11). It was observed that administration of 25-50 g fenugreek seeds daily to the diet of diabetic patients showed that fenugreek fiber significantly reduced the glycemic index (GI) (31). On the other hand, water extract of fenugreek seeds has higher hypoglycemic and antihyperglycemic potential; for this reason, it may be used as a supplementary medicine to treat the diabetic population by significantly reducing the dose of standard drugs.

It has been reported that addition of fenugreek (5.5 g) to 50 g carbohydrate portions of white bread and jam and fried rice meaningfully diminishes incremental area under the plasma glucose response curve (IAUC). It was noted that postprandial plasma glucose and satiety (PPG) remarkably decreased and increased, respectively, in the obese persons (39).

Cholesterol lowering effect: There are different important scientific information and clinical data on the efficacy of dietary fiber, especially the soluble counterparts such as beta-glucans or galactomannans in the management of hypercholesterolemia. Fenugreek derived galactomannans, due to their unique structure of galactose to mannose 1:1 ratio, to have the maximum efficacy in lowering the plasma cholesterol level (17). Furthermore, soluble fiber fractions reduce only the dangerous low-density lipoproteins and triglycerides intake, whereas keeping the good high-density cholesterols intact (40).

In a study on 60 diabetic individuals with high cholesterol and triglycerides level, who regularly received 25 g of fenugreek fiber powder containing nearly 50 % fiber content, a significant decrease was observed in blood glucose, LDL cholesterol and triglycerides level whereas HDL level had no decrease (41). The biochemical mechanism of soluble fiber as a hypolipidemic agent can be explained primarily by its capacity to bind bile acids, which are, therefore, excreted rather than recycled to the blood reduced cholesterol. Fermentation of soluble fiber by bacteria in the clone produces short-chain fatty acids, which can reduce cholesterol synthesis (42).

Eidi *et al*. (2007) reported that an ethanolic extract of FEN decreased total cholesterol and triacylglycerol in streptozotocin-induced diabetic rats. The mechanism was not determined, but the hypolipidemic effect could be because of the inhibition of carbohydrate and fat absorption due to the fibre contained in the extract (43). Raju and Bird (2006) observed a reduction in liver weight and less marbling of liver fat during supplementing the diet of Zucker obese rats with 5 % FEN seed when compared to obese controls (44). The effects of two concentrations of FEN seed powder (12.5 g and 18.0 g/ day) on the blood lipid profile of human subjects over a month were studied by Sowmya and Rajyalakshmi (1999) (31). They understood that both concentrations led to a reduction in total cholesterol and LDL. It is to be noted that there are several published studies on the hypolipidemic potential of fenugreek in animals, while only a few ones in humans. Some of the mechanisms proposed for the effects are stimulation of bile formation in the liver, transformation of cholesterol into bile acids and production of volatile fatty acids by fiber fermentation, which seem to prevent hepatic cholesterol synthesis (11).

Effect on constipation and irregularity: Fenugreek fiber could be useful for treating constipation and hinder the development of diverticulosis and diverticulitis. Fenugreek fiber promotes the normal location due to imperfect fermentation in the large intestine. It can make the waste bulky, soften the stool by holding water, and minimize the transit time through the intestine; hence, it helps to keep constant and steady stool time (45).

Effect on body weight and obesity: It was observed that the food rich in dietary fiber and protein could increase the secretion of anorexigenic, insulinotropic hormones, and glucagon-like peptide-1 (GLP-1) to improve glucose tolerance and reduce weight gain (46). It has been indicated in some studies, that fenugreek seed extract supplementation is effective in reducing the body and adipose tissue weights. The probable mechanism may be due to flushing out of the carbohydrates from the body before entering the blood stream resulting in weight loss and high content of soluble fiber in fenugreek that forms a gelatinous structure; this in turn has effects on slowing the digestion and absorption of food from the intestine and creates a sense of satiety (47).

Anticarcinogenic effect and antioxidant activity: Low consumption of fiber in a diet can induce colon cancers and irritable bowel syndromes. Anaerobic bacterial fermentation of dietary fiber produces short-chain fatty acids like butyrate, which is thought to protect against colon carcinogenesis (48). The anticarcinogenoic activity of fenugreek has been reported in several studies. Incorporation of fenugreek seed in the diet modulates the activity of *β*-glucoronidase and mucinase, and inhibits coloncarcinogenesis. Activity of *β*-glucoronidase significantly decreased the free carcinogens, which were not affective on colonocytes. Mucinase helped in hydrolysing the protective mucin, and this was correlated with the presence of fiber, flavanoids and saponins (49).

Since the antioxidant activity of a plant is due to its active phytochemicals, it has been announced that fenugreek possesses a great antioxidant property that has a beneficial effect on the liver and pancreas because of its phenolic and flavonoid compounds. It has been stated that fenugreek seed extract reduces lipid peroxidation and hemolysis in RBC (50). Dixit *et al*. (2005) have shown that the aqueous fraction of fenugreek exhibits higher antioxidant activity compared with other fractions (51). Fenugreek extract scavenges hydroxyl radicals and inhibits H_2O_2-induced lipid peroxidation in the liver mitochondria of rats (52).

Germinated fenugreek seeds showed more beneficial than dried seeds due to the fact that the bioavailability of different constituents of fenugreek seeds increases by germination (53). In fact, significant antioxidant activity in germinated fenugreek seeds may be related to the presence of flavonoids and polyphenols. It was reported that mustard and fenugreek seeds have hypoglycemic and antihyperglycemic activities in diabetic mice, which could be due to the presence of antioxidant carotenoids in these spices (54).

Application as a galactagogues

Since ancient times, herbs and natural substances have been traditionally used to improve milk production. Fenugreek is one of the most frequently used galactagogues that stimulate breast milk secretion. It is speculated that fenugreek induces sweat production, and since the breast is a modified sweat gland, it affects on breast milk secretion. It may be synthetic, plant-derived, or endogenous (55). It has also been demonstrated that fenugreek has esterogenic activity that is effective on breast milk production (56). Sreeja *et al*. (2010) proposed that fenugreek seeds contain estrogen-like compounds, which stimulate pS2 expression in MCF-7 cell lines (57). Turkyılmaz *et al*. (2011) stated that phytoestrogens and diosgenin of fenugreek appear to account for increase in the milk flow (58).

A report summarized the anecdotal account of approximately 1200 women over 6 years, who were supplemented with commercially available fenugreek. They used 2 to 3 capsules (580 or 610 mg) 3 times a day. It was reported that most of these women experienced an increase in their milk supply within 24 to 72 hours of use (59). In another study, 75 puerperal women consumed fenugreek herbal tea or palm dates, and the effect on breast milk production was evaluated. The milk amount was measured on the third postpartum day. The infants were weighed on days 0, 3, 7 and 14 using an infant scale. Milk volume and infant weight significantly differed either in the dates or in the fenugreek and control groups. Only infant weights in the dates' group showed an increasing trend on the seventh day and there was not any remarkable difference among them on the fourteenth day. It was concluded that palm dates and fenugreek herbal tea seemed to be applicable in the early postpartum period for enhancing breast milk production (60). In a study carried out in Turkey, the effect of herbal tea containing fenugreek on breast milk production and weight gain recovery of the infants within the first postpartum week was evaluated. Sixty-six women were randomly assigned into 1 of 3 groups to receive herbal tea with fenugreek, herbal tea with apple as a placebo, or no tea as a control for the duration of birth weight recovery. The results revealed that the herbal tea with fenugreek group had almost double mean volume of pumped milk (73 mL) as compared to the placebo (39 mL) and control groups (31 mL). The galactagogue group also had a lower maximum weight loss and shorter time to recovery of birth weight compared to both the placebo and control groups (58).

Application of fenugreek in food

Fenugreek can modify food texture owing to the high content of proteins and fibers, especially a soluble dietary fiber called gum (about 20.9 g/100 g in the seed), as well as neutral detergent. This fiber content, in addition to the flavor components modulates the organoleptic properties of foods. Soluble fibers can be utilized in nutrition and cereal bars, yogurts, dairy products, and nutritional beverages. Plain powders of soluble fiber or total dietary fiber can be mixed with fruit juices, other spice mixes and seasonings. It can also be formulated as tablets or capsules along with the other vitamins and nutrients for direct supplements. It might further be applied to milk shakes, soups, dressings, sweets and candies or to fortify bakery flour for pizza, bread, pizza, bagel, muffins, cake mix, noodles, tortilla, flat bread, and fried and baked corn chips (1, 11).

In general, fenugreek is beneficial to food processing as food stabilizer, food adhesive, food emulsifier and gum (6). The molecular weight of fenugreek gum is increased by removing the attached proteins. Viscosity of fenugreek gum increases with increase in gum concentration or with a reduction of the residual protein attached. However, residual proteins play an important role in decreasing the tension at the oil-water interface but they do not have any meaningful impact on the surface activity of the fenugreek gum (9, 18). It has been 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. Also the solubility and emulsifying properties of soy protein isolate with fenugreek gum dispersions are stable over a wide range of pH, ion strength and high temperature (61). Hooda and Jood (2004) noted that the addition of 10% of fenugreek flour to wheat flour increased protein content, fiber, total calcium and total iron; this indicates that fenugreek can be incorporated to prepare acceptable biscuits, and may also be mixed with cereals as a supplement for some limiting amino acids, and hence, for improving their protein quality through amino acid balance (62). Losso *et al.* (2009) found no significant differences in color, texture, proximate composition, firmness, and flavor intensity between the fenugreek and wheat bread, whereas glucose and insulin was lower in the bread with fenugreek (63). The substitution of 2.5, 5, 7.5 and 10% seed powder was evaluated on the textural and quality characteristics of vermicelli; the stress value increased from 0.03 to 0.037 N/m^2 though the stickiness level declined from 67 to 48 g with increase in the fenugreek level. The data on sensory quality characteristics of vermicelli showed an improvement in appearance and strand quality as the fenugreek level was increased. However, at 10% substitution, both the mouth feel and flavor were affected. The highest overall quality score was related to vermicelli with 7.5% fenugreek, and it had slightly thicker matrix than the control according to the surface scanning electron micrographs (64).

Impact of fenugreek seed flour as antioxidant and antimicrobial agent in formulation of beef burger was studied. Fenugreek seed flour (at 3, 6, 9 and 12% levels) was used in the production of beef burgers instead of soybean flour. This substitution improved the content of essential amino acids, and caused an improvement or retention of physiochemical quality criteria (pH value, WHC, cooking shrinkage, TVN and TBA contents) during frozen storage improved the microbiological quality in comparison to the control sample. Also beef burger samples containing FSF exhibited good sensory properties and better acceptability, especially those contained 3 and 6% FSF, even after frozen storage for 3 months (65). The effect of addition of fenugreek seed husk (FSH) in muffins at different levels (5%, 10% and 15%) was examined. Muffins made with FSH at various levels and batter flow characteristics were investigated. By increasing the FSH content from 0 to 15%, the viscosity of muffin batter raised from 32,500 to 38,000 cps.

The muffin volumes increased up to 10% addition of FSH and further FSH increase had no beneficial effect. Supplementation of muffins with FSH led to a decrease in texture hardness from 4.20 to 3.19 N. The muffins containing fenugreek seed powder had higher acceptability than the controls. Based on the sensory quality of muffins, the best level of FSH flour was determined to be 10%, and the amount of dietary fiber was two (65).

In another study, the effects of fenugreek flour and de-bittered fenugreek polysaccharide on the physical and sensory quality characteristics and glycemic index (GI) of chickpea–rice-based extruded products were investigated.

A mixture of 70:30 chickpea and rice, containing various contents of fenugreek flour (2%, 5% and 10%) and polysaccharide (5%, 10%, 15% and 20%), was extruded. Due to bitter taste of fenugreek, it was not possible to add more than 2% fenugreek flour. An increase in longitudinal expansion and a decrease in radial expansion occurred as a consequence of addition of fenugreek polysaccharide. The products consisting fenugreek polysaccharide up to 15% were acceptable by the panelists, and it was possible to add de-bittered polysaccharide of fenugreek up to a level of 15% in a chickpea-rice mixture to achieve snack products with appropriate physical and sensory properties plus having low GI (66). In a study carried out by Metwal *et al.* (2011), a mixture of debittered and defatted fenugreek seed powder (70%) and flaxseed powder (30%) was utilized in cookies. By increasing the level of aforementioned ingredients from 10 to 30% in the blend, its ash, fat and protein, dough development time, resistance to extension and peak viscosity value were increased. However, addition of more than 20% resulted in poor quality of the cookies, whereas utilizing soya lecithin could improve the overall acceptability of the cookies with 20% mixture. Compared with the control cookies, linolenic acid (2.3%) and total dietary fiber (13.04%) level of the cookies with 20% mixture and lecithin was four and two times more, respectively. Surface scanning electron microscopy of cookies with different levels of the mixture from 10 to 30% showed that there was a disruption in the matrix (67). Figure 4 shows the advantages of using fenugreek in foods.

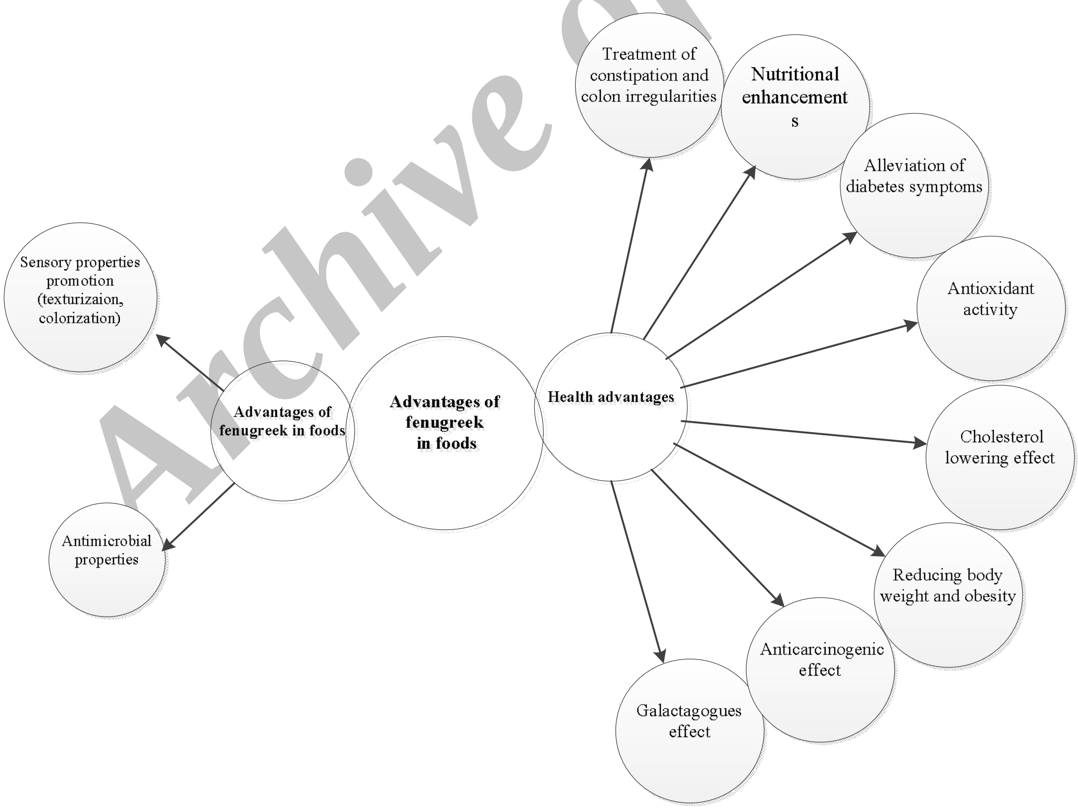

Fig 4. Advantages of fenugreek addition to foods

Conclusion

Over the last few years, several studies have been conducted on the medicinal and functional properties of fenugreek seeds. Fenugreek is rich in fiber, and protein, and due to its valuable bioactive components, it has promising therapeutic applications. Antidiabetic, antioxidant, anticarcinogenic, hypoglycemic and hypocholesterolemic activities are the major medicinal properties of fenugreek as demonstrated in various studies. Based on these healthy benefits, fenugreek can be recommended to be a part of our daily diet and incorporated into foods in order to produce functional foods.

Financial disclosure

The authors declared no financial interest.

Funding/Support

The study did not receive any financial support.

References

1. Im KK, Maliakel BP. Fenugreek dietary fibre a novel class of functional food ingredient. Agro Food Industry Hi-Tech. 2008;19(2):18-21.
2. Betty R. The many healing virtues of fenugreek. Spice India. 2008;1:17-9.
3. Trivedi PD, Pundarikakshudu K, Rathnam S, Shah KS. A validated quantitative thin-layer chromatographic method for estimation of diosgenin in various plant samples, extract, and market formulation. Journal of AOAC International. 2007;90(2):358-63.
4. Madhava Naidu M, Shyamala B, Pura Naik J, Sulochanamma G, Srinivas P. Chemical composition and antioxidant activity of the husk and endosperm of fenugreek seeds. LWT-Food Science and technology. 2011;44(2):451-6.
5. Mathur P, Choudhry M. Consumption Pattern of Fenugreek Seeds in Rajasthani Families. J Hum Ecol. 2009;25(1):9-12.
6. Jani R, Udipi S, Ghugre P. Mineral content of complementary foods. The Indian Journal of Pediatrics. 2009;76(1):37-44.
7. Işıklı ND, Karababa E. Rheological characterization of fenugreek paste (çemen). Journal of food engineering. 2005;69(2):185-90.
8. Meghwal M, Goswami T. A review on the functional properties, nutritional content, medicinal utilization and potential application of Fenugreek. J Food Process Technol. 2012;3:1-10.
9. Youssef M, Wang Q, Cui S, Barbut S. Purification and partial physicochemical characteristics of protein free fenugreek gums. Food hydrocolloids. 2009;23(8):2049-53.
10. El Nasri NA, El Tinay A. Functional properties of fenugreek (< i> Trigonella foenum graecum</i>) protein concentrate. Food Chemistry. 2007;103(2):582-9.
11. Srinivasan K. Fenugreek (Trigonella foenum-graecum): A review of health beneficial physiological effects. Food reviews international. 2006;22(2):203-24.
12. Parthasarathy VA, Chempakam B, Zachariah TJ. Chemistry of spices: CABI; 2008.
13. Sharma R, Raghuram T, Rao NS. Effect of fenugreek seeds on blood glucose and serum lipids in type I diabetes. Eur J Clin Nutr. 1990;44(4):301-6.
14. Madar Z, Shomer I. Polysaccharide composition of a gel fraction derived from fenugreek and its effect on starch digestion and bile acid absorption in rats. Journal of Agricultural and Food Chemistry. 1990;38(7):1535-9.
15. Mathern JR, Raatz SK, Thomas W, Slavin JL. Effect of fenugreek fiber on satiety, blood glucose and insulin response and energy intake in obese subjects. Phytotherapy research. 2009;23(11):1543-8.
16. Song BK, Winter WT, Taravel FR. Crystallography of highly substituted galactomannans: fenugreek and lucerne gums. Macromolecules. 1989;22(6):2641-4.
17. Brummer Y, Cui W, Wang Q. Extraction, purification and physicochemical characterization of fenugreek gum. Food Hydrocolloids. 2003;17(3):229-36.
18. Garti N, Madar Z, Aserin A, Sternheim B. Fenugreek galactomannans as food emulsifiers. LWT-Food Science and Technology. 1997;30(3):305-11.
19. Ramesh H, Yamaki K, Ono H, Tsushida T. Two-dimensional NMR spectroscopic studies of fenugreek galactomannan without chemical fragmentation. Carbohydrate polymers. 2001;45(1):69-77.
20. Huang X, Kakuda Y, Cui W. Hydrocolloids in emulsions: particle size distribution and interfacial activity. Food Hydrocolloids. 2001;15(4):533-42.
21. Kumar P, Kale R, McLean P, Baquer N. Antidiabetic and neuroprotective effects of Trigonella foenum-graecum seed powder in diabetic rat brain. Prague Med Rep. 2012;113(1):33-43.
22. Uemura T, Goto T, Kang MS, Mizoguchi N, Hirai S, Lee JY, et al. Diosgenin, the main aglycon of fenugreek, inhibits LXRα activity in HepG2 cells and decreases plasma and hepatic triglycerides in obese diabetic mice. The Journal of nutrition. 2011;141(1):17-23.
23. Singh V, Garg A. Availability of essential trace elements in Indian cereals, vegetables and spices using INAA and the contribution of spices to daily dietary intake. Food Chem. 2006;94(1):81-9.
24. Fæste CK, Namork E, Lindvik H. Allergenicity and antigenicity of fenugreek (Trigonella foenum-graecum) proteins in foods. J Allergy Clin Immun. 2009;123(1):187-94.
25. Mehrafarin A, Qaderi A, Rezazadeh S, Naghdi-Badi H, Noormohammadi G. Zand. E. Bioengineering of

Important Secondary Metabolites and Metabolic Pathways in Fenugreek (Trigonella foenum-graecum L.). J Med Plants. 2010;9(35):1-18.

26. Shang M, Cai S, Han J, Li J, Zhao Y, Zheng J, et al. Studies on flavonoids from Fenugreek (Trigonella foenumgraecum L.). Zhongguo Zhong Yao Za Zhi. 1998;23(10):614-6, 39.

27. Skaltsa H. 9 Chemical constituents. Fenugreek: the genus Trigonella. 2002:132.

28. Yadav UC, Baquer NZ. Pharmacological effects of Trigonella foenum-graecum L. in health and disease. Pharm Biol. 2014;52(2):243-54.

29. Benayad Z, Gómez-Cordovés C, Es-Safi NE. Identification and quantification of flavonoid glycosides from fenugreek (Trigonella foenum-graecum) germinated seeds by LC–DAD–ESI/MS analysis. J Food Compost Anal. 2014;35(1):21-9.

30. Izzo AA, Di Carlo G, Borrelli F, Ernst E. Cardiovascular pharmacotherapy and herbal medicines: the risk of drug interaction. Int J Cardiol. 2005;98(1):1-14.

31. Sowmya P, Rajyalakshmi P. Hypocholesterolemic effect of germinated fenugreek seeds in human subjects. Plant Food Hum NutR. 1999;53(4):359-65.

32. Girardon P, Bessiere J, Baccou J, Sauvaire Y. Volatile constituents of fenugreek seeds. Planta Med. 1985;51(6):533-4.

33. Blank I, Lin J, Devaud S, Fumeaux R, Fay LB, editors. The principal flavor components of fenugreek (Trigonella foenum-graecum L.). ACS Symposium Series; 1997: ACS Publications.

34. Hammerness P, Basch E, Ulbricht C, Barrette E-P, Foppa I, Basch S, et al. 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 J, Rokeya B, Faruque O, Nahar N, Mosihuzzaman M, Azad Khan A, et al. Effect of soluble dietary fibre fraction of Trigonella foenum graecum on glycemic, insulinemic, lipidemic and platelet aggregation status of Type 2 diabetic model rats. J Ethnopharmacol. 2003;88(1):73-7.

36. Hannan J, Ali L, Rokeya B, Khaleque J, Akhter M, Flatt P, 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. Brit J Nutr. 2007;97(03):514-21.

37. Ou S, Kwok K-c, Li Y, Fu L. In vitro study of possible role of dietary fiber in lowering postprandial serum glucose. J Agr Food Chem. 2001;49(2):1026-9.

38. Sharma R, Sarkar A, Hazara D, Mishra B, Singh J, Sharma S, et al. Use of fenuqreek seed powder in the management of non-insulin dependent diabetes mellitus. Nutr Res. 1996;16(8):1331-9.

39. Robert SD, Ismail AA-S, Wan Rosli WI. Trigonella foenum-graecum seeds lowers postprandial blood glucose in overweight and obese individuals. J Nutr Metab. 2014;2014.

40. Boban PT, Nambisan B, Sudhakaran PR. Hypolipidaemic effect of chemically different mucilages in rats: a comparative study. Brit J Nutr. 2006;96(06):1021-9.

41. Favier M-L, Moundras C, Demigné C, Rémésy C. Fermentable carbohydrates exert a more potent cholesterol-lowering effect than cholestyramine. Biochim. Biophys. Acta 1995;1258(2):115-21.

42. Peran L, Sierra S, Comalada M, Lara-Villoslada F, Bailón E, Nieto A, et al. A comparative study of the preventative effects exerted by two probiotics, Lactobacillus reuteri and Lactobacillus fermentum, in the trinitrobenzenesulfonic acid model of rat colitis. Brit J Nutr. 2007;97(01):96-103.

43. Eidi A, Eidi M, Esmaeili E. Antidiabetic effect of garlic (Allium sativumL.) in normal and streptozotocin-induced diabetic rats. Phytomedicine. 2006;13(9):624-9.

44. Raju J, Bird R. Alleviation of hepatic steatosis accompanied by modulation of plasma and liver TNF-α levels by Trigonella foenum graecum (fenugreek) seeds in Zucker obese (fa/fa) rats. Int J Obesity. 2006;30(8):1298-307.

45. Johanson JF. Review of the treatment options for chronic constipation. Med Gen Med. 2007;9(2):25.

46. Reimer RA, Russell JC. Glucose tolerance, lipids, and GLP-1 secretion in JCR: LA-cp rats fed a high protein fiber diet. Obesity. 2008;16(1):40-6.

47. Geetha M, Suneel K, Krupanidhi A, Muralikrishna K, Avin A, Prashanth P. Effect of fenugreek on total body and organ weights: A study on mice. Pharmacologyonline. 2011;3:747-52.

48. Schatzkin A, Mouw T, Park Y, Subar AF, Kipnis V, Hollenbeck A, et al. Dietary fiber and whole-grain consumption in relation to colorectal cancer in the NIH-AARP Diet and Health Study. Am J Clin Nutr. 2007;85(5):1353-60.

49. Devasena T, Menon VP. Fenugreek affects the activity of β-glucuronidase and mucinase in the colon. Phytother Res. 2003;17(9):1088-91.

50. Kaviarasan S, Vijayalakshmi K, Anuradha C. Polyphenol-rich extract of fenugreek seeds protect erythrocytes from oxidative damage. Plant Food Hum Nutr. 2004;59(4):143-7.

51. Dixit P, Ghaskadbi S, Mohan H, Devasagayam T. Antioxidant properties of germinated fenugreek seeds. Phytother Res. 2005;19(11):977-83.

52. Kaviarasan S, Anuradha C. Fenugreek (Trigonella foenum graecum) seed polyphenols protect liver from alcohol toxicity: a role on hepatic detoxification system and apoptosis. Int J Pharm. Sci 2007;62(4):299-304.

53. Altuntaş E, Özgöz E, Taşer ÖF. Some physical properties of fenugreek (Trigonella foenum-graceum L.) seeds. J Food Eng. 2005;71(1):37-43.

54. Grover J, Yadav S, Vats V. Medicinal plants of India with anti-diabetic potential. J Ethnopharmacol. 2002;81(1):81-100.

55. Danditiya H, Singh G, Kashaw S. The galactagogues used by indian tribal communities to overcome poor lactation. IJBBR . 2013;4(3):243-8.

56. Betzold CM. Galactagogues. J Midwifery Wom Heal. 2004;49(2):151-4.

57. Sreeja S, Anju V, Sreeja S. In vitro estrogenic activities of fenugreek Trigonella foenum graecum seeds. Indian J Med Res. 2010; 131:814-819.

58. Turkyılmaz C, Onal E, Hirfanoglu IM, Turan O, Koç E, Ergenekon E, et al. The effect of galactagogue herbal tea on breast milk production and short-term catch-up of birth weight in the first week of life. J Altern Complement Med. 2011;17(2):139-42.

59. Huggins K. Fenugreek: One remedy for low milk production. Rental Roundup. 1998;15(1):16-7.

60. El Sakka A, Salama M, Salama K. The effect of fenugreek herbal tea and palm dates on breast milk production and infant weight. J Pediatr Sci (ISSN: 1309-1247). 2014;6.

61. Hefnawy HTM, Ramadan MF. Physicochemical characteristics of soy protein isolate and fenugreek gum dispersed systems. J Food Sci Tech. 2011;48(3):371-7.

62. Hooda S, Jood S. Nutritional evaluation of wheat–fenugreek blends for product making. Plant Food Hum Nutr. 2004;59(4):149-54.

63. Losso JN, Holliday DL, Finley JW, Martin RJ, Rood JC, Yu Y, et al. Fenugreek bread: a treatment for diabetes mellitus. J Med Food. 2009;12(5):1046-9.

64. Jyotsna R, Indrani D, Sai Manohar R, Venkateswara Rao G. Effect of fenugreek (Trigonella Foenum Graecum L.) on the textural characteristics and microstructure of vermicelli from triticum durum wheat semolina. J Food Process Pres. 2011;35(3):320-6.

65. Hegazy A. Influence of Using Fenugreek Seed Flour as Antioxidant and Antimicrobial Agent in the Manufacturing of Beef Burger with Emphasis on Frozen Storage Stability. World J Agric Sci. 2011;7(4):391-9.

66. Shirani G, Ganesharanee R. Extruded products with Fenugreek (Trigonella foenum-graecium) chickpea and rice: Physical properties, sensory acceptability and glycaemic index. J Food Eng. 2009;90(1):44-52.

67. Metwal N, Jyotsna R, Jeyarani T, Venkateswara Rao G. Influence of debittered, defatted fenugreek seed powder and flaxseed powder on the rheological characteristics of dough and quality of cookies. Int J Food Sci Nutr. 2011;62(4):336-44.