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Review Article

Fenugreek: potential applications as a functional food and nutraceutical

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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 it medicinal effects. Fenugreek seeds are rich source of gum, fiber, alkaloid, flavonoids, saponin and volatile content. Due to it's high content of fiber, fenugreek could be used as food stabilizer, adhesive and emulsifying agent to change food texture for some special purposes. Some evidences suggest that fenugreek may also be regarded as antidiabetic, anticarcinogenic, remedy for hypocholesterolemia and hypoglycemia, antioxidant, antibacterial agent, gastric stimulant, and anti-anorexia agent. The present article is aimed to review the potential applications of fenugreek as a functional food and nutraceutical.

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

Introduction

Increasing demand of consumers for healthy foods has urged the food industry to develop food products that promote health. Foods that provide significant nutrition, exert health advantages, inhibit disease and/or assist health have become more readily accepted by the industry and can be used as successful marketing tools. This has caused the emergence of functional foods that comprise a wide range of components such as probiotics, prebiotics, vitamins, minerals and dietary fiber (1). In this respect, some herbs have been considered for their application as an antioxidant, antimicrobial, health promotion and food development.

Fenugreek (*Trigonella Foenum-gracium*) is a plant from the family of *Leguminosae* that grows annually and is widely cultivated in Mediterranean countries and Asia (Figure 1). The dried seeds have been traditionally used in India, China, Egypt and in some parts of Europe for their beneficial health effects such as, galactogouge, antibacterial, anti-inflammatory, insulinotropic, and rejuvenating effects (2). 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 seed have horny and relatively large layer of white and semi-transparent endosperm encircling central hard, yellow embryo (3).

Wonderful functional and medicinal values of fenugreek are attributed to its chemical composition (20-25% proteins, 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 component for its various biological effects (4).

Regarding the composition of fenugreek seeds, husk and cotyledons it has been reported that endosperm

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had the highest saponin (4.63 g/100 g) and protein (43.8 g/100 g) content, whereas husk had higher total polyphenols (103.8 mg of gallic acid equivalent/g, and total dietary fiber (TDF) (77.1 g/100 g), comprising insoluble dietary fiber (IDF) (31.9 g/100 g) and soluble dietary fiber (SDF) (45.2 g/100 g). It is observed that 200 µg concentrations, extracts of husk, fenugreek seed, and endosperm showed 72%, 64%, and 56% antioxidant activity, respectively, by free-radical scavenging method (5). It has been shown that fenugreek has antidiabetic, anticancer, hypocholesterolemic, anti-inflammatory, antioxidant and chemopreventive 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

Proteins: It was found that 100 g endosperm contains protein of 43.8 g (5, 6). However, 100 g of fenugreek seed contained 25.4 g protein (7). 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 had high potential for insulin-stimulating activity (8). Fenugreek protein fraction is rich of lysine and can be compared with soybean protein (9). 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 the more increase in gum concentration or decrease in residual protein attached, the more increase in viscosity is resulted (10). 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 were low at pH 4.5 which is the isoelectric point of the proteins. Moreover, they reported that fenugreek protein concentrate showed 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 protein of fenugreek seeds were more soluble in acidic (4.5) and alkaline (12) conditions than at nearly neutral pH (11). Srinivasan (2006) demonstrated that the quality of fenugreek seed proteins was not affected by cooking (12).

Vitamins and minerals: Although fenugreek is relatively low in mineral content, some are present in good concentrations such as phosphorus and sulphur (11) and also it has been reported that curry made from fenugreek has a high amount of calcium, iron and zinc (7). Table 1 provides an overview of vitamins and minerals and their levels in fenugreek seeds. From the other point of view, germinating seeds have pyridoxine, cyanocobalamine, calcium pantothenate, biotin and vitamin C (13).

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 the ones for seed were 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 vegetables 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 (12).

Fibers and gums: Fenugreek seeds are rich source of soluble dietary fiber (14). The 100 g of seeds provides more than 65% of dietary and contains saponins, hemicelluloses, mucilage, tannins and pectin, which help to decrease the level of low density lipoprotein-cholesterol (LDL) in blood by decreasing bile salts re-absorption in the colon. Also, it has been reported that

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fenugreek fiber bound to toxins in the food and helped to protect the colon mucus membrane from cancer toxins as well as lowering the rate of glucose absorption in the intestines controlling blood sugar levels. Furthermore, the fibers can exhibit prebiotic effects via beneficial health effects on the health of the host through modulation of the intestinal flora (15). One of the major soluble fibers of the fenugreek seeds is galactomannan which decreases the bile salts uptake in the intestine and also reduces the digestion and absorption of starch in body (16, 17). 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 (5).

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	-
vitamins	
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) and they differ from each other by the mannose/galactose (M/G) ratio (18). Galactomannan has a property of increasing viscosity when dissolved in the water and these properties make it an excellent ingredient for various food applications over the other natural hydrocolloids (19). Fenugreek galactomannan can be used as a stabilizer for food. Interfacial and surface tension reduction properties of fenugreek gum is comparable to Arabic gum.

Galactomannan in fenugreek can decrease surface tension even to levels lower than 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 gum, implying its emulsification properties to be superior 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 (20).

Ramesh *et al*. (2001) found that fenugreek galactomannan lose 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 (21). It has been reported that that purified fenugreek gum including 0.8% residual protein, could reduce the surface tension and form stable emulsions with small oil droplets (2-3 µm) (19). 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 (22).

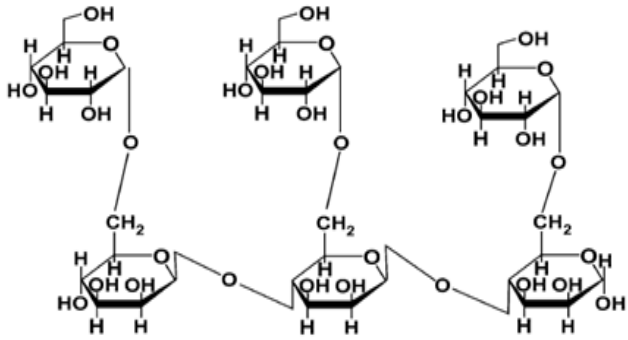

Fig 2. Fenugreek galactomannan structure.

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Alkaloid, flavonoids and saponin: Fenugreek contains different alkaloids, flavonoids and saponins (23, 24) that the latter one is in the highest concentration (25). Alkaloid and volatile constituents of fenugreek seeds are the two major components which cause bitter taste and bad odor (26). The level of flavonoid in fenugreek is more than 100 mg per g of seed (5). The main alkaloids, flavonoids and saponons are shown in figure 3 (27-30). Benayad *et al* (2014) investigated the phenolic compounds of fenugreek crude seeds from Morocco by HPLC–DAD–ESI/MS. Analysis 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 (31). The alkaloids, flavonoids and saponins of fenugreek showed pharmacological effect. They have antilipidemic, hypoglycaemic and cholagogic properties and their use could manage diabetes mellitus, hypercholesterolemia due to clinical evidence which shows serum cholesterol level reduction. Beside of useful properties it should be carefully taken in order to avoid minor gastrointestinal symptoms and allergic reactions (32).

Volatile compounds: Volatile oils in fenugreek are in small quantities (33). There were 39 different compounds that were identified by Girardon et al. (1985), 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(5H)-furanone), which is present in concentrations up to 25 ppm (34). Blank et al. (1997) also detected some odorous compounds in fenugreek seeds are implied in Table 2 (35).

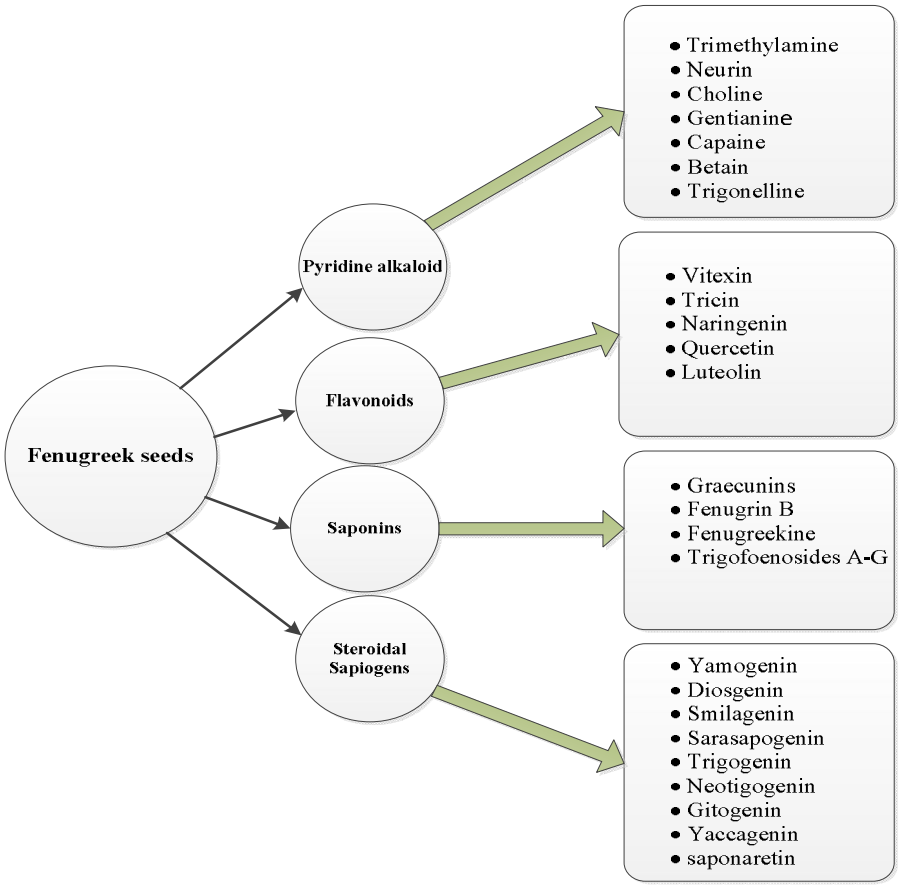

Fig 3. The main alkaloids, flavonoids, saponins and steroidal sapiogens in fenugreek seeds

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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 fenugreek powder containing 50 percent dietary fiber for a period of 10 days decreased 25 percent blood glucose level among the type II diabetes patients (36). It has been shown that soluble fiber fraction reduced postprandial elevation in blood glucose level of Type 2 model diabetic rats by hindering the digestion of sucrose. Administering fenugreek soluble fiber orally twice daily at a dose of 0.5 g/ 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 it could inhibit platelet aggregation in Type 2 model diabetic rats (37). Moreover, it has been reported that soluble fiber of fenugreek postpones digestion and absorption of carbohydrate resulting improvement of glucose homeostasis (38). 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 (39).

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 amount of unabsorbed sucrose in the gastrointestinal tract of non-diabetic and type 2 diabetic rats increased after oral consuming of sucrose.

Increment of blood glucose after oral sucrose ingestion in both non-diabetic and type 2 diabetic was hindered by the SDF fraction (38). Sharma *et al*. (1996) studied fenugreek seed powder in order to determine its effects on glycemia and insulinemia in 60, T_2 diabetes mellitus patients. Fenugreek seed powder (25g) was administered daily for 24 weeks. It resulted in a reduction in blood glucose 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 urinary sugar and glycosylated hemoglobin were also significantly reduced by 13% and 12.2%, respectively (40). 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 diabetic subjects when 10 g of the whole seed powder was consumed 3 hours before a glucose load whereas no effect was seen in healthy subjects in the same condition. It could be explained by viscous properties

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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 leaves had the weakest effect (12). It was observed that administration of 25-50 g fenugreek seeds daily to diabetic patients in diet showed that fenugreek fiber significantly reduced the glycemic index (33). On the other hand, water extract of fenugreek seeds has higher hypoglycemic and antihyperglycemic potential and 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 is reported that addition of fenugreek (5.5 g) to 50 g carbohydrate portions of white bread and jam and fried rice meaningfully diminish incremental area under the plasma glucose response curve (IAUC) in comparison with food without fenugreek. It is noted that postprandial plasma glucose and satiety (PPG) remarkably decreased and increased respectively between obese persons (41).

Cholesterol lowering effect: There are different important scientific information and clinical data done on the efficacy of dietary fiber, especially the soluble counterpart such as beta-glucans or galactomannans in the management of hypercholesterolemia. Fenugreek derived galactomannans, due to its unique structure of galactose to mannose 1:1 ratio, have shown to have the maximum efficacy in lowering the plasma cholesterol level (19). Furthermore, soluble fiber fractions reduce only the dangerous low-density lipoproteins and triglycerides intake, whereas keeping the good high-density cholesterols intact (42).

In a study which was done on 60 individuals with diabetes and high cholesterol and triglycerides level, who regularly received 25 g of fenugreek fiber powder containing nearly 50 percent fiber content, a significant decrease in blood glucose, LDL cholesterol and triglycerides level up was shown whereas HDL level had no decrease (43). 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 blood cholesterol. Fermentation of soluble fiber may be done by bacteria in the clone which produce short-chain fatty acids can reduce cholesterol synthesis (44).

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 due to the inhibition of carbohydrate and fat absorption due to the fibre contained in the extract (45). Raju and Bird (2006) reported that a reduction in liver weight and less marbling of liver fat was observed during supplementing the diet of Zucker obese rats with 5 % FEN seed when compared to obese controls (46). 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 was studied by Sowmya and Rajyalakshmi (1999) (33). They understood that both concentrations led to a reduction in total cholesterol and low-density lipoprotein (LDL). It should 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 which proposed for the effects are stimulation of bile formation in the liver and the transformation of cholesterol into bile acids, the viscosity of the digest reducing cholesterol and bile acid absorption and the production of volatile fatty acids by fiber fermentation, which seems to prevent hepatic cholesterol synthesis (13).

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 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 (47).

Effect on body weight and obesity: It was observed that the food rich in dietary fiber and protein could increase secretion of the anorexigenic and insulinotropic hormone, glucagon-like peptide-1 (GLP-1) to improve glucose tolerance and reduce weight gain (48). It has been indicated in some studies, that fenugreek seed extract supplementation is effective in reducing the body and adipose tissue weight. The probable mechanism may be due to flushing out the carbohydrates from the body before

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entering the blood stream resulting in weight loss and high content of soluble fiber in fenugreek that forms a gelatinous structure which may have effects on slowing the digestion and absorption of food from the intestine and create a sense of satiety (49).

Anticarcinogenic effect and antioxidant activity: Cancer is a very serious and complicated disease created by out of control and irregular growth of cell, whose prevalence is remarkably increasing. Except for genetic defects which contribute to 5 to 10% of cancer incidences, the rest (90% to 95%) can be limited by changing lifestyle, increasing physical activity, avoiding smoking and utilizing nutritionally balance diet together with the foods free from contaminants (50). 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 (51). The anticarcinogenoic activity of fenugreek has been reported in several studies. Incorporation of fenugreek seed in the diet modulates the activities of β-glucoronidase and mucinase and inhibit 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 fibre, flavanoids and saponins (52).

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 compound. It has been stated that fenugreek seed extract reduces lipid peroxidation and hemolysis in RBC (53). Dixit *et al*. 2005 have shown that the aqueous fraction of fenugreek exhibit higher antioxidant activity compared with other fractions (54). Fenugreek extract scavenges hydroxyl radicals and inhibits H_2O_2-induced lipid peroxidation in rat liver mitochondria (55).

Germinated fenugreek seeds showed more beneficial than dried seeds due to the fact that the bioavailability of different constituents of fenugreek seed were increasesed by germination (56). 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 showed hypoglycemic and antihyperglycemic activities in diabetic mice, which could be due to the presence of antioxidant carotenoids in those spices (57).

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, affect breast milk secretion. It may be synthetic, plant-derived, or endogenous (58). It has also been demonstrated that it has esterogenic activity that is effective on breast milk production (59). Sreeja *et al*. (2010) proposed that fenugreek seeds contain estrogen-like compounds which stimulate pS2 expression in MCF-7 cell lines (60). Turkyılmaz *et al*. (2011) stated that phytoestrogens and diosgenin of fenugreek appear to account for the increase in milk flow (61).

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 women experienced an increase in milk supply within 24 to 72 hours of use (62). In another study, seventy-five puerperal women consumed fenugreek herbal tea or palm dates and the effect on breast milk production was evaluated. Milk amount was measured on the third postpartum day. Infants were weighed on days 0, 3, 7, and14, using an infant scale.

Milk volume and infant weight significantly differed in either dates or fenugreek groups and control group. Among dates, fenugreek and control groups, only infant weights in date's group showed an increasing trend on the seventh day and there wasn't any remarkable difference among them on the fourteenth day. It was concluded that in early postpartum period, palm dates and fenugreek herbal tea seems to be applicable for enhancing breast milk production (63). In a study carried out in Turkey, the effect of herbal tea containing fenugreek on breast milk production and weight gain recovery of infants within the first postpartum week was evaluated. Sixty-six women were randomly assigned to 1 of 3

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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 the mean volume of pumped milk (73 mL) as compared to the placebo (39 mL) and control group (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 (61).

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), and also 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 also 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 and flat bread, fried and baked corn chips (2, 12).

In general, fenugreek is beneficial to food processing as food stabilizer, food adhesive, food emulsifier and gum (7). 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 played 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 (10, 19). It was 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. It was also observed that solubility and emulsifying properties of soy protein isolate with fenugreek gum dispersions were stable over a wide range of pH, ion strength and high temperature (64). 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 (65). Losso *et al.* (2009) understood that there were no significant differences in color, texture, proximate composition, firmness, and flavor intensity between the fenugreek and wheat bread, whereas glucose and insulin was found to be lower in the bread with fenugreek (66). The substitution of 2.5, 5, 7.5 and 10% seed powder was evaluated on textural and quality characteristics of vermicelli. The stress value increased from 0.03 to 0.037 N/m^2, although the stickiness level declined from 67 to 48 g with the increase in fenugreek level, respectively. The data on sensory quality characteristics of vermicelli showed that there was an improvement in appearance and strand quality as fenugreek increased. However, at 10% substitution, the mouthfeel 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 surface scanning electron micrographs (67).

Impact of fenugreek seed flour application as antioxidant and antimicrobial agent in formulation of beef burger was studied. Fenugreek seed flour at levels of 3, 6, 9 and 12% was used in 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 beside of improving of the microbiological quality in comparison to the control sample. Also, beef burger samples containing FSF exhibited a good sensory properties and better acceptability, especially those contained 3 and 6%, even after frozen storage for 3 months (68). The effect of addition of fenugreek seed husk (FSH) in muffins at different levels of 5%, 10% and 15% was examined. Muffins were made with FSH at various levels and batter flow characteristics were investigated. By increasing FSH content from 0 to 15%, the viscosity of muffin batter raised from 32,500 to 38,000 cps

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The muffin volumes increased up to 10% addition of FSH and further FSH increase did not result beneficially. 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 control. Based on sensory quality of muffins, the best level of FSH flour was determined to be 10% and the amount of dietary fiber was two (68).

In another study, the effects of fenugreek flour and de-bittered fenugreek polysaccharide addition on the physical and sensory quality characteristics, and glycemic index (GI) of chickpea–rice based extruded products was 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 wasn't possible to add more than 2% fenugreek flour. An increase in longitudinal expansion and a decrease in radial expansion were occurred as a consequence of addition of fenugreek polysaccharide. The products consisting fenugreek polysaccharide up to 15% were acceptable by panelist 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 besides of having low GI Index (69). 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, ash, fat and protein, dough development time, resistance to extension and peak viscosity values increased. However addition more than 20% resulted in poor quality of cookies whereas utilizing soya lecithin could improve overall acceptability of the cookies with 20% mixture. Compared with the control cookies, level of linolenic acid (2.3%) and total dietary fiber (13.04%) 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 (70). Figure 4 shows the advantages of fenugreek to be used in foods.

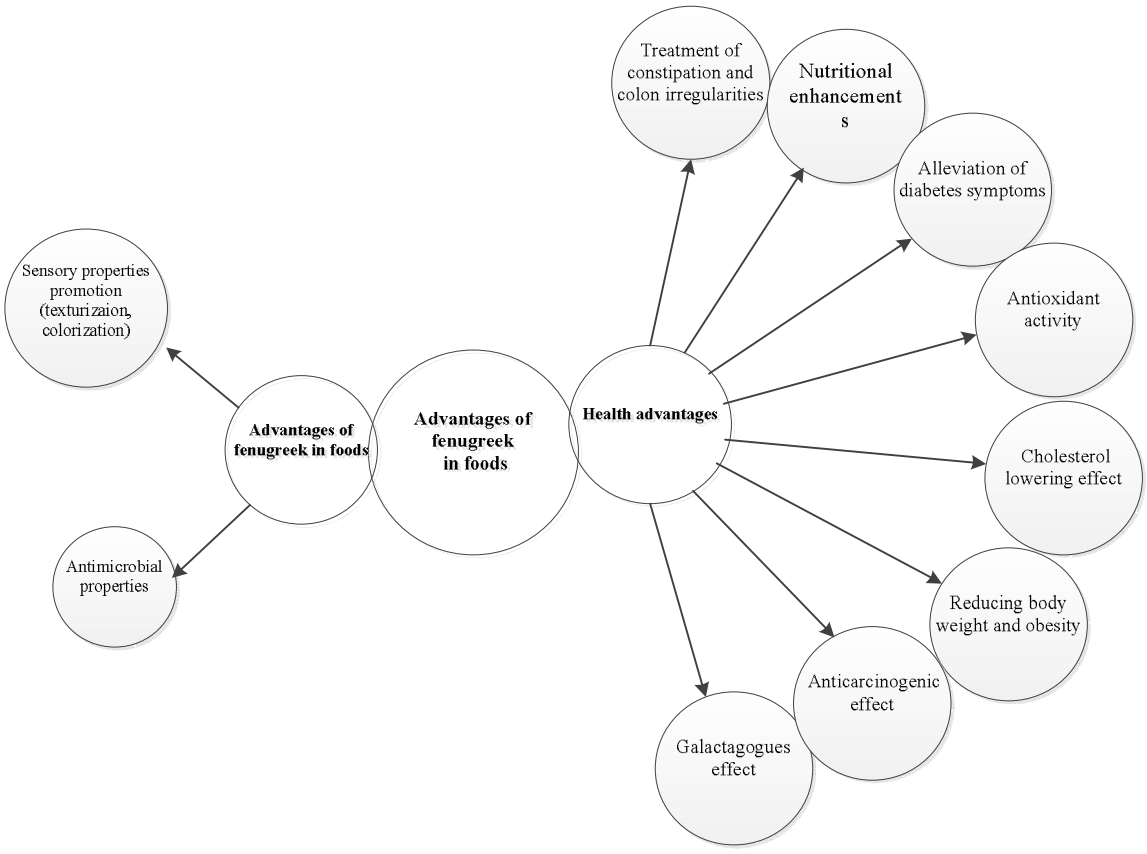

Fig 4. Advantages of fenugreek addition to foods

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Conclusion

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

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