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A review: Food, medicinal and nutraceutical properties of fenugreek (*Trigonella Foenum-Graecum L.*)

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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 a medicinal plant that use in disease some therapy. The plant contains active constituents such as alkaloids, flavonoids, steroids, Saponins etc. Fenugreek is known to have antidiabetic, anticarcinogenic, hypocholesterolemic, antioxidant, and immunological activities. Recent research has identified fenugreek as a valuable medicinal plant with potential for curing diseases and also as a source for preparing raw materials of pharmaceutical industry, like in steroidal hormones. Application of fenugreek has been found to be lethal against hazardous bacteria, specifically coli forms, *Pseudomonas* spp., *Shigella dysenteriae* and *Salmonella typhi*. These properties probably make fenugreek a valuable ingredient in food and pharmaceutical applications. 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.

Keywords: Fenugreek, food, nutraceutical properties, medicinal properties

Introduction

Fenugreek (*Trigonella foenum graecum*) is self-pollinated an annual plant belongs to the family Leguminosae. It was called as "*Trigonella*" from Latin language that means "Little triangle" due to its yellowish-white triangular flower (Flammang *et al.*, 2004)^[1] and species name "*Foenum-graecum*" means "Greek hay" indicating its use as a forage crop in the past. Fenugreek have originated in the Mediterranean region of the parts of Asia and recently it was suggested so as to fenugreek originated in Turkey. Fenugreek is known all over the world (Table 1). About 260 species are currently available in *Trigonella* genus. Most of the species include *Trigonella foenum graecum* L. are diploids with 2n=16 chromosomes but some other species may include 18, 30, 32 or 44, 99 chromosomes (Acharya *et al.*, 2014)^[2].

Table 1: Common names of Fenugreek (*Trigonella foenum graecum*).

Language	Common Names
Hindi	Methi, Saag methi, Kasuri methi
English	Fenugreek
French	Fenugreec, Trigonelle
Galician	Alforfa
German	Bockshornklee, Griechisch Heu
Georgian	Solinji, Chaman
Japanese	Koruha, Fenu-guriku
Dutch	Fenugriek
Romanian	Molotru, Molotru comun, Schinduf
Assamese	Methi, Miithi
Sanskrit	Methika

In India, Fenugreek is grown in an area of 134 ('000 hectares) producing about 180.8 ('000 MT), where as in Rajasthan grown in an area of 81.70 ('000 hectares) with a production of 84.20 ('000 MT) in 2014-15 (Anonymous, 2017) [3]. It is exported to Saudi Arabia, Japan, Korea, Srilanka and UK. The major states growing in India are Rajasthan, Madhya Pradesh, Gujarat, UP, Maharashtra, Karnataka and Punjab.

Fenugreek has been used both as a herb (the leaves) and as a spice (the seed) and also used to increase the flavor, colour and texture of the food materials, these days it is used as food stabilizer, adhesive and emulsifying agent due to its high fiber, protein and gum content (Meghwal and Goswami, 2012)[4]. Seed of fenugreek contain a substantial amount of phospholipids, glycolipids, oleic acid, linolenic acid, linoleic acid (Suliman *et al.*, 2000; Chatterjee *et al.*, 2010) [5, 6], choline, vitamin A, B1, B2, C, nicotinic acid, niacin (Leela and Shafeekh, 2008) [7], and many other functional elements. It also has some medicinal properties such as antioxidant, anticancer, antidiabetic, lactation aid, hypocholesterolemic, antimicrobial, gastric simulant for anorexia and hepatoprotective (Srinivasan, 2006) [8].

Morphology of fenugreek (*Trigonella foenum graecum*)

Fenugreek (*Trigonella foenum graecum*) seeds sprout within 3 days in a well prepared soil. Fenugreek was described to have two types of flowering shoots and flowers related to its growth habit. Cleistogamous (closed) and aneictogamous (open) flowers are two flower types of which first is common and latter is rare. Similarly, axillary shots are common showing an indeterminate growth habit, whereas the less common blind shoots" have both axillary and terminal flowers, each of which become "tip bearers" (Mehrafarin *et al.*, 2011) [9]. Darlington and Wylie (1955) [10] have classified the plants as self and cross pollinated and suggested that the plants to be self-fertile based on floral physiology of fenugreek plants. As per Allard (1960) [11], legumes are considered cross pollinated when more than 10% of them are outcrossed. Stigma of fenugreek becomes receptive before the anthers mature making it rarely cross pollinated. In the second stage of floral development, when the stamens are lower in position than the stigma, i.e. when the anthers are closed but the stigma is receptive to pollination, cross pollination can be achieved for breeding purposes detailed morphological characteristics of fenugreek are given in Table 2.

Table 2: Morphological characteristics of Fenugreek (*Trigonella foenum graecum*)

Morphological characteristics	Description, color and texture	Dimensions	Reference
Plant habit	Erect or prostrate, Straight or profusely branched	20-130 cm in length	Flammang <i>et al.</i> , 2004 ^[12] , Srinivasan 2006 ^[8]
Stem	Circular to slightly quadrangular, greenish, often characterized by pinkish color due to anthocyanin accumulation under field conditions	0.5-1 cm in diameter	Blank 1996 ^[13] ; Sowmya <i>et al.</i> , 1996 ^[14] , Moradi and Moradi 2013 ^[15]
Leaf	Pale green, pubescent, often anthocyanin tinged	Very small; 0.5-1.1 mm	Brar <i>et al.</i> , 2013 ^[16]
Flower	Yellow when young but white on maturity	1.6-2.2 cm	Montgomery, 2009 ^[17] , Mehrafarin <i>et al.</i> , 2011 ^[9]
Seed	Rectangular to oval in shape with deep grooves between the radical and cotyledon. Varies in color form pale brown to golden Yellow	10-20/pod 3-5 mm X 2-3 mm	Bala 2003 ^[18] . Srinivasan, 2006 ^[8] , Sowmya <i>et al.</i> , 1996 ^[14]

Chemical constituents of fenugreek (*Trigonella foenum-graecum*)

Fenugreek has been referred to as a medicinal herb both in Indian ayurvedic and traditional Chinese medicines (Tiran 2003) [19]. It contains a number of chemical constituents protein, starch, neutral detergent fiber, ash and lipids (Gupta *et al.*, 1998) [20]. Generally, three important chemical constituents of fenugreek are very important; i.e. 1) steroidal saponin; 2) galactomannans and 3) isoleucine. These constituents have placed fenugreek among the most commonly recognized "nutraceutical" or health food products (Srichamroen *et al.*, 2008) [21]. Three main constituents of fenugreek are saponins, flavonoids and alkaloids. The bitter taste and specific smell of fenugreek is due to alkaloids and some other volatile compounds (Altuntas *et al.*, 2005) [22].

Fiber

The fiber content of fenugreek seed extract plays a role in its ability to moderate metabolism of glucose in the digestive tract. Fenugreek can be used as source of natural antioxidants because of the fiber content (Raju *et al.*, 2001) [23]. The 100 g of seeds gives more than 65% of dietary fibers. Dietary fiber of fenugreek can exert short term beneficial effects by reducing energy intake and increasing satiety as per one of the study conducted on obese people. It was reported that fiber of

the fenugreek bind to cancer causing toxins of the intestine and removes them; it also lowers the rate of glucose absorption and helps in controlling blood sugar level (Meghwal and Goswami, 2012) [4].

Protein

Fenugreek endosperm is highly rich in protein such as globulin, albumin, histidine and lecithin. Seed of fenugreek has a high proportion of protein ranging from 20 to 30% as well as amino acid, 4-hydroxyisoleucine, which contains high potential for insulin-stimulating activity (Isikli and Karababa, 2005) [24]. Fenugreek proteins are stable enough, and are not affected during cooking. Moreover, debitterized fenugreek seeds are rich in protein and lysine contents (Srinivasan, 2006) [8].

Vitamins and Minerals

Fenugreek seed is a rich source of vitamins viz. vitamin A (3 ug/100g), B1 (0.43 mg/100g), B2 (0.36 mg/100g), C (12-43 Mg/100g), nicotinic acid (1.1 Mg/100g) and niacin (6 mg/100g). Its leaves also contain vitamins, but on boiling, steaming or frying, 7-11% of them may be lost. Fenugreek seeds contain of potassium (603.0 mg/100g), magnesium (42.0 mg/100g), calcium (75.0 mg/100g), Zinc (2.4 mg/100g) and iron (25.8 mg/100g) (Al Jasass and Al Jasass, 2012) [25].

Alkaloids, saponin and flavonoids in fenugreek (*Trigonella foenum-graecum*)

Fenugreek contains (Table. 3) a fairly high amount of alkaloids, saponins and flavonoids. Alkaloids and volatiles are the two major constituents of fenugreek seed which causes bitter taste. Fenugreek endosperm contains 35% alkaloids, primarily trigonelline. Flavonoid constitutes more than 100

mg/g of fenugreek seed (Naidu *et al.*, 2011) [26]. All these compounds are classified as biologically active as these have pharmacological effects on the human body when ingested. Their use should, therefore, be promoted in daily diet to manage hypercholesterolemia, cancer and diabetes mellitus as they possess hypoglycemic, antilipidemic, anticarcinogenic and cholagogic properties (Meghwal and Goswami, 2012) [4].

Table 3: Alkaloids, saponin and flavonoids of fenugreek and their classification

Chemical Group	Compounds	References
Alkaloids	Trigonelline, choline, carpaine	Rababah <i>et al.</i> , 2011 ^[27]
Flavonoids	Naringenin, lilyn, kaempferol, vecenin-1, tricin 7-O-D glucopyranoside, saponaretin, isovitexin, isoorientin. Orientin, vitexin, luteolin, quercetin	Blumenthal <i>et al.</i> , 2000 ^[28]
Saponins	Fenugrin, foenugracin, glycoside, yamogenin, trigonoesides, smilagenin, gitogenin, sarsasapogenin, yuccagenin, hederagin, diosgenin, tigonenin, neotigogenin	Meghwal and Goswami, 2012 ^[4]

Nutraceutical and Medicinal Properties of Fenugreek (*Trigonella Foenum-Graecum*)

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 (Table 4) to relieve colds, bronchial complaints, influenza, asthma, catarrh, constipation, sinusitis, pleurisy, pneumonia, sore throat, laryngitis, hay fever tuberculosis and emphysema (Anon., 2013) [29].

Antioxidant Effect

Fenugreek contains phenolic and flavonoid compounds which help to enhance its antioxidant capacity. Balch (2003)^[18] suggested that fenugreek has powerful antioxidant property that has beneficial effect on liver and pancreas; since antioxidant properties have been linked to health benefits of natural products; such properties are studied with germinated fenugreek seeds which are observed to be more beneficial than dried seeds because of the fact that germinated seed increases the bioavailability of different constituents of fenugreek. The seed extract exhibited scavenging of hydroxyl radicals and inhibition of hydrogen peroxide-induced LPO in mitochondria of rat liver cells. The OH scavenging activity of the extract was demonstrated by pulse radiolysis and the deoxyribose system. The fenugreek seeds extract contains antioxidants and protects cellular structures from oxidative damage. An aqueous methanolic extract of fenugreek was investigated for its antiradical and invitro antioxidant activity in various model systems. The results gained by different methods provide some important factors responsible for the antioxidant activity of fenugreek seeds (Kaviarasan *et al.*, 2007) [30].

Table 4: Pharmacological and therapeutic benefits of fenugreek (*Trigonella foenum-graecum*)

Disease/Disorder	Description	Reference
Anemia	Prevents red blood cell oxidation	Kaviarasan <i>et al.</i> , 2007 ^[30]
Aging	Antioxidants improves reduces cell death and aging	Kaviarasan <i>et al.</i> , 2004 ^[31]
Cancer	Polyphenolic compounds from seed possess anti-carcinogenic activities	Mohamed <i>et al.</i> , 2015 ^[32]
Diabetes	4-hydroxyisoleucine (amino acid) stimulates insulin production thereby control blood sugar level. Polyphenolic compounds exhibit anti-diabetic effects. Curative effects of fenugreek seed powder is a potential neuropathic medicine in diabetes	Kaviarasan <i>et al.</i> , 2007 ^[30] , Nanjundan <i>et al.</i> , 2009 ^[33]
Hypercholesterolemia	Anti-oxidants from seeds control high blood cholesterol	Srinivasan, 2006 ^[8]
Immunodeficiency	Natural antioxidants help to strengthen immune system immunomodulatory and immune stimulatory effects	Kaviarasan <i>et al.</i> , 2004 ^[31]
Indigestion and flatulence	Fenugreek has been used as laxative. It stimulates appetite and act as laxative	Platel and Srinivasan 2000 ^[34]
Inflammation	Reduces swelling and pain	Kaviarasan <i>et al.</i> , 2007 ^[30]
Kidney disorders	Protects functional and histopathologic abnormalities of kidney in diabetic patients. Reduces catalase (CAT) contents and superoxide dismutase (SOD) activity in hypercholesterolemia patients. Inhibit accumulation of oxidized DNA to prevent kidney injuries	Xue <i>et al.</i> , 2011 ^[35]
Others	Respiratory disorders, bacterial infection, epilepsy, gout, chronic cough, paralysis, dropsy, piles, heavy metal toxicity, liver disorders and arthritis	Nanjundan <i>et al.</i> , 2009 ^[33] , Xue <i>et al.</i> , 2011 ^[35] , Kaviarasan <i>et al.</i> , 2007 ^[30]

Anticancer Effect

Trigonella foenum-graecum seeds showed potential protective activity against 7, 12 dimethylbenz (a) anthracene-induced

breast cancer in rats at 200 mg/kg of body weight and the extract significantly inhibited the DMBA-induced mammary-hyperplasia and decreased its incidence. The ethanolic extract

of fenugreek seeds with an ED50 less than 10µg/ml in the brine shrimp cytotoxicity assay, was also observed to possess anti-tumour activity in A-549 male lung carcinoma, MCF-7 female breast cancer. Further studies concluded that fenugreek is a safe medicinal herb for complementary therapy in cancer patients because fenugreek extract shows a protective effect by modifying the cyclophosphamide induced apoptosis and lipid peroxidation in the urinary bladder of experimental mice (Lee 2009) [36]. Fenugreek contains a crystalline steroid saponin, Diosgenin as a starting material for the synthesis of steroid hormones such as cortisone and progesterone. It has the potential to prevent invasion, suppress proliferation and osteoclastogenesis through inhibition of necrosis factor and enhances apoptosis induced by cytokines and chemotherapeutic agents (Montgomery 2009) [17].

Anti-diabetic effect

The harmful side effects of synthetic drugs, the enormous cost and in the capacity of existing modern techniques to control all pathological aspects and the poor advance therapies for many rural populations in developing countries. Galactomannan, a soluble fiber is isolated from Canadian grown fenugreek seeds, responsible for reduction of postprandial blood glucose level. Because of its viscous property, galactomannan has ability to reduce intestinal absorption of high or low concentration of glucose, so that there is the benefit of blood glucose control (Srichamroen *et al.*, 2008) [21].

When the fenugreek seed powder treatment for 21 days to diabetic rats brought down the high fasting blood glucose levels to control levels. The enzyme activities were restored to control values in both the kidney and liver. The anti-diabetic actions of fenugreek seeds have been considered as to the presence of steroid saponins and fiber content in the seeds (Sauvaire *et al.*, 1996) [37]. The effect of oral administration [5% in the diet] of powder of fenugreek seeds in alloxan-induced diabetic rats for 21 days were investigated, the glycolytic, NADP linked lipogenic and gluconeogenic enzymes were determined in the kidney and liver tissues of rats (Raju *et al.*, 2001) [23]. The *T. foenum graecum* saponin fraction significantly modulated the glycogen enzyme and disaccharidase activities in the intestine; it suppressed the increase of blood sugar level, increased the hepatic glycogen content and improved results in the oral glucose tolerance test. The fenugreek saponin also protected the liver function, which occurred due to the significant increases of superoxide dismutase, catalase, glutathione peroxidase, aspartate transaminase, lactate dehydrogenase, alanine transaminase enzyme activities. Fenugreek saponins reveal attractive qualities and can be considered as capable for potential purpose, mainly those related to the improvement of anti-diabetic, hepatoprotective and hypolipidemic drugs (Hamden *et al.*, 2010) [38].

Antibacterial effect and Antifungal effect

The antibacterial and antifungal role of fenugreek is recently being shown. In a study by Haouala *et al.*, (2008)[39], 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*. The effectiveness of extracts obtained from fenugreek against *Helicobacter pylori* has been reported by several studies (O'Mahony *et al.*, 2005; Randhir

et al., 2004; Randhir and Shetty, 2007) [40, 41, 42]. 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) [43]. 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) [44].

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. 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 (Snehlata and Payal, 2012) [45].

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 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) [4].

Fenugreek on Digestion

Spices consumed in diet positively influenced the pancreatic digestive enzymes. Platel and Srinivasan (2000)[34] 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 bowel movement. Also, non-starchy polysaccharides assist in smooth digestion whereas high fiber of fenugreek helps in relieving constipation ailments.

Utilization of fenugreek in various food products

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 (Table 5). 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) [46].

Table 5: Food and non-food applications of fenugreek

Application/Uses	Plant part	Reference
Bread making	Seeds	Meghwal and Goswami, 2012 ^[4]
Functional food	Galactomannan, fiber and extract	Meghwal and Goswami, 2012 ^[4]
Flavoring agents	Seeds, leaves (condiments, pickles, curries)	Srinivasan, 2006 ^[8]
Alcoholic beverages	Seeds	Jani <i>et al.</i> , 2009 ^[47]
Stabilizer, Adhesive and Emulsifying agent	Seeds	Jani <i>et al.</i> , 2009 ^[47]
Cosmetics	Leaves, seeds	Meghwal and Goswami, 2012 ^[4]
Insect repellent	Seeds oil	Meghwal and Goswami, 2012 ^[4]
Fumigant	Leaves	Srinivasan, 2006 ^[8]

Fenugreek as food stabilizer, food adhesive and food emulsifier

The interaction of fenugreek protein with the food constituents determines its ability to stabilize and emulsify the food constituents. Hefnawy and Ramadan (2011) [48] 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) [36]. Sowmya and Rajyalakshmi (1999) [14] 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) [49].

Fenugreek in traditional food

Fenugreek paste locally termed as “Cemen” is a popular food in Turkey, which is prepared from ground fenugreek seeds. Crushed fenugreek seed or coarse fenugreek powder is used to make ball for making clarified butter (Isikli and Karababa, 2005) [24].

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. 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) [50].

Losso *et al.*, (2009) [51] 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.

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) [52].

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, 2016) [53].

Fenugreek gum (extruded and nonextruded) 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 (G₀) and

loss modulus (G00). 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) [54].

Conclusions

Fenugreek having antidiabetic, antifertility, anticancer, antimicrobial, antiparasitic, lactation stimulant and hypocholesterolemic 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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