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

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Received 5 December 2015; revised 15 January 2016; accepted 21 January 2016

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

KEYWORDS
Fenugreek; Nutraceutical; Hypoglycemic; Antioxidant; Extruded product

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jssas.2016.01.007

Please cite this article in press as: Wani, S.A., Kumar, P. Fenugreek: A review on its nutraceutical properties and utilization in various food products. Journal of the Saudi Society of Agricultural Sciences (2016), http://dx.doi.org/10.1016/j.jssas.2016.01.007.
1. Introduction

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

26. Anticancer effect

2.7. Antibacterial and antifungal effect

2.8. Advantages of fenugreek on digestion

3. Utilization of fenugreek in various food products

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

3.2. Fenugreek in traditional food

3.3. Fenugreek in bakery products

3.4. Fenugreek in extruded product

4. Conclusions

References
on the fenugreek aroma detection with the help of Gas Chromatograph and these includes the olfactometry diacetyl, 1-Octene-3-one, sotolon, acetic acid; 3-Isobutyl-2-methoxy pyrazine, butanoic acid, isovaleric acid, 3-isopropyl-2-methoxy pyrazine, caproic acid, elegant, 3-Amino-4,5-dimethyl-3, linalool, (Z)-1,5-Octadiene-3-one, 4-dihydro-2 (5H)-Furanone with characteristic aroma of buttery like, roasty/earthy, metallic, pungent, paprika like, sweaty/rancid, flowery, musty, spicy respectively. Out of all these volatile compounds, sotolon was reported to be found most predominantly in (5s)-enantiomeric form (95%) in fenugreek.

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

### Table 1 Chemical constituents of fenugreek.

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Chemical constituents of fenugreek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaloids</td>
<td>Trimethylamine, Neurin, Trigonelline, Choline, Gentianine, Carpaine and Betain</td>
</tr>
<tr>
<td>Amino acids</td>
<td>Isoleucine, 4-Hydroxyisoleucine, Histidine, Leucine, lysine, L-tryptophan, Arginine</td>
</tr>
<tr>
<td>Saponins</td>
<td>Graecunins, fenugrin B, fenugreekine, trigofenosides A-G</td>
</tr>
<tr>
<td>Steroidal sapinogens</td>
<td>Sarsasapogenin, tigogenin, neotigogenin, gitogenin, neogitogenin, yuccagenin, saponaretin</td>
</tr>
<tr>
<td>Flavonoids</td>
<td>Quercetin, rutin, vitexin, isovitexin</td>
</tr>
<tr>
<td>Fibers</td>
<td>Gum, neutral detergent fiber</td>
</tr>
<tr>
<td>Lipids</td>
<td>Triacylglycerols, diacylglycerols, monoacylglycerols, phosphatidylcholine phosphatidylethanolamine, phosphatidylinositol, free fatty acids. (Chatterjee et al., 2010)</td>
</tr>
<tr>
<td>Other</td>
<td>Coumarin, lipids, vitamins, minerals. 28% mucilage; 22% proteins; 5% of a stronger-swelling, bitter fixed oil. (Yadav et al., 2011), Sowmya and Rajyalakshmi (1999).</td>
</tr>
</tbody>
</table>

The medicinal value of fenugreek seeds is mentioned in Ayurvedic texts as well as in Greek and Latin pharmacopoeia. The Ayurvedic texts praise this herb for its power as an aphrodisiac, but modern vaidyas seem to be using it more for digestive and respiratory problems stemming from an excess of kaph (phlegm) and vat (wind). In ancient Egypt, methi was used to ease childbirth and to increase milk flow, and modern Egyptian women are still using it today to relieve menstrual cramps, as well as making hilba tea out of it to ease other kinds of abdominal pain. The Chinese call it hu lu ba, and also use it for treating abdominal pain. Though this cool season crop is grown in most corners of the world, its uses and people's awareness of its value vary considerably. In India, fresh methi ka saag (the stems and leaves of the plant) is very commonly cooked as a winter vegetable, and the seeds are used year-round as a flavoring agent for various dishes. The seeds are also eaten raw as sprouts and used medicinally. In Egypt...
Table 2 Nutraceutical properties of fenugreek.

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Component used</th>
<th>Beneficial effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Seeds</td>
<td>Hypoglycemic effect (Roberts, 2011)</td>
</tr>
<tr>
<td>2</td>
<td>Seeds</td>
<td>Hypocholesterolemic effect (Zia et al., 2001; Srivastava et al., 2012)</td>
</tr>
<tr>
<td>3</td>
<td>Seed, leaves</td>
<td>Antioxidant (Bukhari et al., 2008; Bhatia et al., 2006; Naidu et al., 2010)</td>
</tr>
<tr>
<td>4</td>
<td>Seed</td>
<td>Lactation aid (Snehlata and Payal, 2012; Al-Shaikh et al., 1999)</td>
</tr>
<tr>
<td>5</td>
<td>Seed</td>
<td>Immunomodulatory effect (Meghwal and Goswami, 2012)</td>
</tr>
<tr>
<td>6</td>
<td>Seed</td>
<td>Digestive effect (Platel and Srivivasan, 2000)</td>
</tr>
<tr>
<td>7</td>
<td>Seeds and leaves</td>
<td>Decreases blood pressure (Sowmya and Rajyalakshmi, 1999)</td>
</tr>
<tr>
<td>8</td>
<td>Seeds and leaves</td>
<td>Wounds and sore muscles treatment (Mathern et al., 2009)</td>
</tr>
<tr>
<td>9</td>
<td>Seeds, leaves</td>
<td>Anti-cancer agent (Sowmya and Rajyalakshmi, 1999; Mathern et al., 2009)</td>
</tr>
<tr>
<td>10</td>
<td>Seeds</td>
<td>Asthma, emphysema, pneumonia</td>
</tr>
<tr>
<td>11</td>
<td>Seeds leaves</td>
<td>Anti-ulcer agent</td>
</tr>
<tr>
<td>12</td>
<td>Seed</td>
<td>Induces growth and reproduction hormones (Blank, 1996)</td>
</tr>
<tr>
<td>13</td>
<td>Leaves and seeds</td>
<td>Gastro- and hepatoprotective (Blank, 1996)</td>
</tr>
<tr>
<td>14</td>
<td>Seed</td>
<td>For healthy heart (Blank, 1996)</td>
</tr>
<tr>
<td>15</td>
<td>Seed</td>
<td>Prevents constipation (Sowmya and Rajyalakshmi, 1999)</td>
</tr>
<tr>
<td>16</td>
<td>Seed</td>
<td>Digestive and appetizer (Sowmya and Rajyalakshmi, 1999)</td>
</tr>
</tbody>
</table>

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

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

2.2. Immunological activity

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

2.3. Hypoglycemic effect

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

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

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

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

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

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

2.4 Hypocholesterolemic effect

The abnormal deficiency of cholesterol level in the blood is known as hypcholesterolemic problem and oral administration of methanolic and aqueous extracts of seeds at a dose of one gram per kilogram body weight resulted in hypoglycemic effect in mice (Zia et al., 2001). Fenugreek seeds contain the large amount of fiber galactose and mannose are the main components of gum. The latter compounds are associated with reduced cholesterol (Roberts, 2011).

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

2.5 Antioxidant activity

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

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

2.6 Anticancer effect

Cancer is one of the leading causes of mortality all around the world. Many reported studies have shown the protective effect of fenugreek seeds in experimental models of cancer using cell lines or experimental animals. Amin et al. (2001) showed that fenugreek seed extract significantly inhibited 7,12-dimethyl benz(a)anthracene-induced mammary hyperplasia and reduces its incidence in rats and advised that the anti-breast cancer protective effects of fenugreek could be due to increased apoptosis. Further, alcoholic whole plant extracts of fenugreek showed in vitro cytotoxicity against different human cancer cell lines such as IMR-32, a neuroblastoma cell line, and HT29, a cancer cell line (Verma et al., 2010). A selective cytotoxic effect of
fenugreek extract in vitro to a panel of cancer cell lines has been observed, including T-cell lymphoma by Alsemari et al. (2014). Sebastian and Thampan (2007) examined the growth of MCF-7 cells, which is an estrogen receptor positive breast cancer cell line, with ethanol extracts of fenugreek, and reported that the ethanol extract of fenugreek decreased cell viability and induced early apoptotic changes such as inversion of phosphatidyl serine and decreased mitochondrial membrane potential. Further, degradation of DNA into fragments comprising multiples of approximately 180–200 base pair has also been observed. Cell cycle analysis revealed a sub-G1 apoptotic population along with cell cycle arrest at G2/M phase in fenugreek extract treated cells implicating the role of fenugreek extract-induced apoptosis in its anticancer role. According to the investigation made by Shabbeer et al. (2009), treatment with fenugreek extract showed growth inhibitory effects on breast, pancreatic and prostate cancer cell lines but primary prostate or immortalized prostate cells remained unaffected. Inhibition of cancer cell growth by Trigonella is attributed to its ability to induce death of cell, despite simultaneous upregulation of growth stimulatory pathways in normal cells. Prabhu and Krishnamoorthy (2010) also demonstrated anticancer activity of the ethanol extract of trigonella in Ehrlich Ascites Carcinoma cells induced cancer in Swiss albino mice. The mice inoculated with Ehrlich Ascites Carcinoma and treated with trigonella leaf extract showed increased life span in comparison with the tumor control, suggesting anticancer activity of fenugreek leaf extract in animal models.

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

### 2.7. Antibacterial and antifungal effect

The antibacterial and antifungal role of fenugreek is recently being shown. In a study by Haouala et al. (2008), an aqueous extracts from various plant parts of fenugreek in various solvents include methanol, petroleum ether and ethyl acetate fractions of the aerial parts and determine their action against fungal strains such as Fusarium graminearum, Botrytis cinerea, Alternaria sp., Rhizoctonia solani and Pythium aphanidermatum. It was found that all parts of the fenugreek plant showed antifungal potential and the magnitude of effect varies with plant parts and species of fungus. It could be suggested that fenugreek is an important source of biologically active compounds useful for developing better and novel antifungal drugs (Haouala et al., 2008). The effectiveness of extracts obtained from fenugreek against Helicobacter pylori has been reported by several studies (O’Mahony et al., 2005; Randhir et al., 2004; Randhir and Shetty, 2007). In a study, honey samples with highest antibacterial activity against Staphylococcus aureus, Pseudomonas aeruginosa and Escherichia coli show maximum pollens from fenugreek than other plants (Mercan et al., 2007). Cysteine-rich peptides, defensins are small with potent antibacterial activity against Staphylococcus aur-

### Table 3 General uses of fenugreek.

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

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

### 3. Utilization of fenugreek in various food products

A list of general uses of various parts of fenugreek in different food products is shown in Table 3 below. Due to rich source of natural dietary fiber in fenugreek, it has established itself in the...
modern food ingredient or functional food. Fenugreek as a hydrocolloid, which is fenugreek gum (soluble fiber of fenugreek), gives textural, appeal, thickening, emulsifying, stabilizing, gelling, and encapsulating properties. So the dietary fiber, more importantly soluble fiber can find their way into nutrition and dairy products, cereal bars, yogurts, and nutritional beverages. The powder of soluble fiber or total dietary fiber can be mixed with juices of fruit, seasonings and other spice mixes. Directly it can be used to formulate tablets or capsules along with the other vitamins and nutrients necessarily needed. It can also be used in milk shakes, dressings, soups, candies and sweets. It has been used to fortify bakery flour for pizza, pizza, cake mix, bread, bagel, muffins, flat bread, tortilla and noodles, fried, baked corn chips. Bakery foods such as bread, pizza, cakes and muffins have been prepared by using flour fortified with eight to ten percent soluble dietary fiber. When fiber fortified flour was used for making oil fried snacks, 8–15% of less oil absorption only takes place which is really appreciable in terms of unwanted fat intake (Im and Maliakel, 2008).

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

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

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

3.2. Fenugreek in traditional food

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

3.3. Fenugreek in bakery products

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

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

In a study incorporation of fenugreek flour up to 10% level has been used in the formulation of biscuits. Baking quality, color attributes and organoleptic evaluation revealed that wheat flour can be replaced using 10% Soaked Fenugreek and 20% Germinated Fenugreek flours to produce acceptable and high nutritional value biscuits. The study confirmed that fenugreek seed (raw, soaked and germinated) significantly reduced total lipids, serum total cholesterol, and LDL-cholesterol but non-significant changes in triglycerides and serum HDL-cholesterol were observed. It can be recommended that fenugreek may be used for lipid lowering purposes (Hussein et al., 2011). Supplementation of basal diets with fenugreek leaves, seeds (dry and germinated) and wheat flour supplemented with germinated fenugreek powder at 5–10% levels increased the total proteins, fibers, iron, zinc, calcium, vitamin B6, carotene, vitamin E and vitamin C contents. These dietary supplements also improve the blood picture of anemic rats so they have nutritive and restorative properties. The daily use of fenugreek products as a dietary supplement is proved to be safe and healthy. Therefore, this study recommends that intake of fenugreek products may be beneficial for patients who suffer from iron deficiency anemia owing to their nutritive and restorative values (Nabila et al., 2012). In the same way 10% germinated fenugreek seed flour has been incorporated into the wheat based biscuits formula resulted in improving their chemical and nutritional quality and additionally also complimented the deficiency of lysine, isoleucine,
leucine, threonine and valine, and hence neutralizes the amino acid imbalance (Hegazy and Ibrahim, 2009).

3.4. Fenugreek in extruded product

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

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

In another study fenugreek gum was extruded in a twin-screw extruder without an exit die to minimize a decrease in molecular weight of fenugreek gum during extrusion process. Both the steady and dynamic shear rheological tests revealed that extrusion process did not substantially influence the steady and dynamic shear properties of the gum. The power law model was applied to describe the flow behavior of the extruded gum solutions. The extrusion modified fenugreek gum solutions exhibited a shear thinning flow behavior at 25 °C, and the values of consistency index and apparent viscosity increased with an increase in the gum concentration. The magnitudes of storage modulus and loss modulus for the extrusion modified fenugreek gum solutions increased with increasing frequency and with increasing gum concentration (Chang et al., 2011). Fenugreek gum (extruded and non-extruded) was substituted for wheat flour at 0%, 5% and 10% (w/w) and the rheological effects and bread making characteristics were determined. Bread containing fenugreek gum (FG) at 5% and 10% showed volumes and texture comparable with control bread. Extruding FG also improved its solubility in bread. Fenugreek gum resulted in an increase in dough farinograph water absorption compared with the control, but in bread. Fenugreek gum resulted in an increase in dough with control bread. Extruding FG also improved its solubility (FG) at 5% and 10% showed volumes and texture comparable with control bread. In this study the addition of fenugreek gum to the extruded pea–rice snack products. In addition to fenugreek gum, two more gums (guar gum and locust bean gum) were added to it. When these three gums were added to the formulations at levels of up to 20%, good expansion of the products occurred. The WAI of the extrudates containing FG increased with increasing inclusion levels. In addition to the high contents of starch that serve to provide energy, these snacks are good sources of protein and dietary fiber, and are low in fat, qualifying them as low Glycemic Index snack products. In particular, the reduction in Glycemic Index was the greatest with fenugreek gum extrudates (Ravindran et al., 2011).

4. Conclusions

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

References

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