A Review on the Functional Properties, Nutritional Content, Medicinal Utilization and Potential Application of Fenugreek

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Abstract

Fenugreek (Trigonella foenum-gracum) is one of the most promising medicinal herbs, known from ancient times, having nutritional value too. Its green leaves and seeds are used for multipurpose. 100 g of seeds provide more than 65% of dietary fibre due to its high fibre content and it has an ability to change food texture. It is well known for its gum, fibre, alkaloid, flavonoids, saponin and volatile contents. In various medicinal applications, it works as antidiabetic, anticarcinogenic, remedy for hypercholesterolemia and hypoglycemia, antioxidant, antibacterial agent, gastric stimulant, and anti-anorexia agent. In modern food technology, it is used as food stabilizer, adhesive and emulsifying agent due its fibre, protein and gum content. Its protein is found to be more soluble (91.3%) at alkaline pH of 11. This review article presents the major medicinal and other beneficial uses of fenugreek discovered through last 30 years of research in animal and human subjects as well as in other experimental studies.

Keywords: Anticarcinogenic; Antidiabetic; Alkaloid; Flavonoid; Saponin; Volatile; Protein; Hypocholesterolemia; Fibre; Hypoglycemia

Introduction

Fenugreek is one of the well known spices in human food. Its seeds and green leaves are used in food as well as in medicinal application which is an old practice of human history. It provides natural food fibre and other nutrients required in human body [1]. Fenugreek has strong spicy and seasoning type sweet flavor [2]. Aromatic and flavourful fenugreek is a popular spice and is widely used for well recognized culinary and medicinal properties [3]. “Kasuri Methi” is very famous for its appetizing fragrance and it is used for culinary preparations [4]. In recent trend, fenugreek is also used as spice adjunct [5]. India is a major producer of fenugreek and also a major consumer of it for its culinary uses and medicinal application. It is used in functional food, traditional food, nutraceuticals as well as in physiological utilization such as antibacterial, anticancer, antiulcer, anthelmintic, hypercholesterolemic, hypoglycemic, antioxidant, and anti diabetic agent. It has beneficial influence on digestion and also has the ability to modify food texture.

Fenugreek is cultivated all over the world as a semi-arid crop. It has got different names as per the locality. Table 1 shows various names of fenugreek in different languages with their country of origin.

Unfortunately, it is learnt from literature that there is no research article which gives an overall view on functional properties, nutritional content, medicinal application and other beneficial applications of fenugreek at one place. Hence, the present review article has been aimed at presenting the titled topic at one place by vigorous review study.

The fenugreek plant

The fenugreek (Trigonella foenum-gracum) seeds sown in well prepared soil sprouts in three days. Seedling grows erect, semi-erect or branched based on its variety and attains a height of 30 to 60 cm. It has compound pinnate, trifoliate leaves, axillary white to yellow flowers, and 3-15 cm long thin pointed hoop-like beaked pods. Every pod contains 10-20 oblong greenish-brown seeds with unique hooplike groves [6]. Pods, number of seeds in a pod, seed shape-size and plant height varies from one fenugreek variety to another. Fenugreek is a self pollinating annual leguminous bean which belongs to Fabaceae family [7]. It is one of the most ancient medicinal herbs [8]. The leaves, flower, calyx, corolla, anthers, stigma, ovary, pods, roots, seeds and stems are major part of this plant. Table 2 shows the scientific classification of this plant as per the taxonomy of plant kingdom [9].

Varieties, speciality and cultivation suitability

Fenugreek is a leguminous plant that helps in nitrogen fixation and soil enrichment [10]. There are different varieties of fenugreek plan to cultivate based on soil and climatic conditions. Some of the major well known varieties (mainly Indian) of fenugreek which are produced all over the world are listed out in Table 3.

Fenugreek plant attains a height of about 1-2 feet. It bears light green coloured slender shaped yellow-brown pods having 10-20 seeds. In this plant flowering starts after 30-40 days of sawing [9].

The green leaves of fenugreek

Green fenugreek leaves are one of the most ancient medicinal herbs [1]. Yadav and Sehgal (1997) [11] found that fresh fenugreek leaves contain ascorbic acid of 220.97 mg per 100 g of leaves and β-carotene of 19 mg per 100 g of leaves. On the other hand, they reported that 84.94 and 83.79 % ascorbic acid was reduced in sun and oven-dried fenugreek leaves respectively. The green fenugreek leaves (fresh or dried) are used as herb. The fresh leaves are used in the vegetables as green leafy vegetable in the diets. They suggested that for better retention of nutrients in fenugreek leaves, it should be stored in refrigeration, dried in oven, blanched for a short period of time (5 min) and should be cooked in pressure cooker. Their studies in 1999 (Yadav and Sehgal) further showed that there is no change in the calcium and zinc content of the processed fenugreek leaves whereas

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| Location specific name of fenugreek | Language | Country | References |
|-------------------------------------|----------|---------|------------|
| Huiba, Huabha, Hheibah, Hheibhe    | Arabic   | Turkey, Hausa | 10 |
| Shambala                            | Armenian | Armenia  | 110        |
| Khilfe, buil                        | Azerbaijani, Azeri, Turki | Azerbaijan, Iran | 2 |
| K’u-tou, hu lu ba                   | Chinese  | China    | 2,10       |
| Piskayika, Diteina rogata           | Croatian | Croatia  | 110        |
| Piskavice, Recke seno               | Czech    | West Slavic | 110       |
| Fenegrieck                          | Dutch    | Portugal | 110        |
| Abish                               | Ethiopian | Ethiopia | 2 |
| Fenugrec                            | French   | France   | 2, 10      |
| Bockshorklee, Kuhhorklee, Bisanklee | German   | Germany  | 10         |
| Trigonikos, Tsimeni, Moschositaro, Tili, Tilipina | Greek | Greece, Cyprus | 110 |
| Methi                               | Hindi    | India    | 10         |
| Goroszena                           | Hungarian | Hungary  | 2          |
| Fiero Greco                         | Italian  | Italy    | 10         |
| Koroha, Koroba                      | Japanese | Japan    | 10, 2      |
| Halba                               | Malay    | Malaysia | 10, 2      |
| Schenlit                            | Persian/Iranian | Iran | 2 |
| Fengrek, kozieradhra                | Polish   | Poland   | 110        |
| Alforra                             | Portuguese | Brazil  | 2          |
| Seneiyka, grecka, seno grecka       | Slovak   | Slovakia | 2          |
| Althonya                            | Spanish  | Spain    | 2, 10      |
| Bockhomsiklerov                     | Swedish  | Sweden   | 110        |
| Pazhilnik                           | Russian  | Russia   | 10         |
| Khufa, u’lBa, boidana                | Uzbekistani | Uzbekistan | 2 |

Table 1: Different names of fenugreek in different languages of the world.

| S.No. | Kingdom | Plantae |
|-------|---------|---------|
| 1.    | Class   | Magnoliopsida |
| 2.    | Order   | Fabales |
| 3.    | Family  | Fabaceae |
| 4.    | Genus   | Trigonella |
| 5.    | Species | T. Foenum-graecum |

Table 2: Position of fenugreek in plant kingdom classification system.

during blanching and cooking HCL extractability for these minerals has increased. Medicinally, fenugreek leaves has been found to have little effect on glycemia [12]. These leaves provide β-carotene, fibre, calcium and zinc [13]. Jani et al. [14] tested about the mineral content of various food items like pulses (dal), bread (chapatti) and fenugreek leaf vegetables by feeding them to children of 13-24 months of age group and found that fenugreek leaves had high calcium, iron and zinc content compared to those available in other food items chosen for this study.

The seeds of fenugreek

Fenugreek seeds are the most important and useful part of fenugreek plant. These seeds are golden-yellow in colour, small in size, hard and have four-faced stone like structure [15]. Fenugreek seed is 3-6 mm long, 2-5 mm wide and 2 mm thick in geometry. Raw fenugreek seeds have maple flavour and bitter taste but by the process of roasting, their bitterness can be reduced and flavour can be enhanced. Fenugreek seeds are used as spices. The whole seed or its ground powder is used in pickles, vegetable dishes and spice powder. Dried seeds are used as condiments. Fenugreek seeds are gummy, fibrous, sticky and gummy in nature. Biologically, its seeds are endospermic in nature [14]. The fenugreek seeds, as a thumb rule, are harvested 150 to 170 days after sowing or 30 to 35 days after flowering [16]. In fenugreek, saponin and alkaloids are anti-nutritional factors [14]. Defatted fenugreek seeds are not bitter in taste and can be easily consumed by those who have problems to consume fenugreek without removing fat, especially by patients. The bitterness of fenugreek can be masked by making formulations with other food ingredients [17].

Volatile content

Fenugreek seed contains volatile oil and fixed oil in small quantities [18]. Blank et al. (1997) [19] has reported the following odour active compounds based on the fenugreek aroma detection with the help of Gas Chromatograph : Olfactometry diacetyl; 1-Octene-3-one; (Z)-1,3-Octadiene-3-one; 3-isopropyl-2-methoxyprazyn; acetic acid; 3-Isobutyl-2-methoxyprazin; linalol; butanic acid; isovaleric acid; capric acid; eugenol; 3-Amino-4,5-dimethyl-3; 4-dihydro-2(SH)-Furanone; sotolon with characteristic aroma of buttery, mushroom like, metallic, roasty / earthy, pungent, paprika like, flowery, sweaty/ rancid, musty, spicy, seasoning like, respectively but out of all these compounds, sotolon was reported to be found predominantly in (5α)-enantiomeric form (95%) in fenugreek.

Mabazaa et al. (2011) studied sweat of human after fenugreek ingestion and concluded that compounds responsible for the strong maple-syrup odor present in sweat after fenugreek ingestion are due to the following compounds: 2,5-dimethylpyrazine; β-pinene; 3-octen-2-one; camphor; terpinen-4-ol; 4-isopropyl-benzaldehyde; neryl acetate and β-caryophyllene but confirmed 2,5-dimethylpyrazine to be a major sweat odor contributing compound.

Fenugreek gum

Fenugreek gum is derived from the endosperm of the seeds. It consists of galactose and manose. It gives high viscosity in the aqueous solution [20]. The fenugreek gum is used for thickening, stabilizing and emulsifying food agents [21,22]. Fenugreek gum is less exploited in the food industry as compared to other gums such as guar and locust bean. Ramesh et al. (2001) [23] reviewed that fenugreek galactomannan is food industry as compared to other gums such as guar and locust bean. Mabazaa et al. (2011) studied sweat of human after fenugreek ingestion and concluded that compounds responsible for the strong maple-syrup odor present in sweat after fenugreek ingestion are due to the following compounds: 2,5-dimethylpyrazine; β-pinene; 3-octen-2-one; camphor; terpinen-4-ol; 4-isopropyl-benzaldehyde; neryl acetate and β-caryophyllene but confirmed 2,5-dimethylpyrazine to be a major sweat odor contributing compound.

Fenugreek fibre

Fenugreek seeds are rich source of soluble dietary fibre content [26]. Raju et al. (2001) [27] reported that the fibre content of fenugreek extract plays a role in its ability to moderate metabolism of glucose in
Table 3: Some of the well known varieties of fenugreek.

| Variety        | Origin                  | Suitable for the region of | Speciality                                  | References |
|----------------|-------------------------|----------------------------|---------------------------------------------|------------|
| RM-1           | SKN CA, Jobner, RAU-Bikaner | Gujarat, Rajasthan         | Semi-erect, tall, bold, yellow grains        | 1          |
| RM-143         | SKN CA, Jobner           | Rajasthan                  | 16 q ha⁻¹                                   | 1          |
| RMt-305        | SKN CA, Jobner           | All fenugreek growing areas | 1300 kg ha⁻¹, dwarf, multipoded, early maturity | 1          |
| NRCSS-AM-1     | NRCSS, Ajmer             | Rajasthan                  | Bold and large seed, specially grown for high yield of leaves. | 1          |
| NRCSS-AM-2     | NRCSS, Ajmer             | Rajasthan                  | Small size seed, specially grown for high yield of leaves. | 1          |
| GM-1           | Gujarat Agricultural University | Gujarat                  | Dwarf, 18.6 q ha⁻¹                            | 1          |
| CO-1           | Tamil Nadu Agricultural University | Tamil Nadu                | Short and green, medium sized brownish orange seeds | 1          |
| Rajendra Kranti | Rajendra Agricultural University | Bihar                    | Tolerant bushy green, seeds are medium sized golden yellow | 1          |
| Lam selection-1 | Andhra Pradesh Agricultural University | Andhra Pradesh | bushy green plant with medium sized golden yellow seeds | 1          |
| Hisar Sonali   | Haryana Agricultural University | Haryana                  | Bushy, semi-erect with bold yellow attractive seeds | 1          |
| Hisar Suvarna  | Haryana Agricultural University | Haryana, Gujarat, Rajasthan | Dual purpose cultivar                       | 1          |
| Hisar Mukta    | CCS Haryana Agricultural University-Hisar | North India             | Resistant to downy mildew, yield 20-23 q ha⁻¹ | 1          |
| HM-350         | CCS Haryana Agricultural University | Haryana                  | Medium in maturity, yield 19-20 q ha⁻¹        | 1          |
| Pant Ragini    | GBPUAT, Pantnagar        | UP                         | Dual purpose, good for leaf and seed purpose, tall, bushy | 1          |
| Pusa Early Bunching | IARI, New Delhi     |                            | Bold seed, quick growing, suitable for seed as well as leaf | 1          |
| Pusa Kasuri    | IARI, New Delhi          |                            | Leaf purpose, small seeds                    | 1          |
| AC Amber       | Developed at Agriculture and Agri-Food Canada, Morden, Manitoba, Canada | Canada                  |                                            | 2          |
| Indian temple  | India                    |                            |                                            | 2          |
| AC Tristar     | Developed at Agriculture and Agri-Food Canada, Lethbridge, Alberta, Canada | Canada                  |                                            | 3          |
| F96            | Italy                    |                            |                                            | 3          |
| F75, F86       | Afghanistan              |                            |                                            | 3          |

The digestive tract. Water absorption on the outer surface makes seeds coat soft and mucilaginous. The 100 g of seeds provide more than 65% of dietary fibre. Non-starch polysaccharides constitute fibre content of the fenugreek. Fenugreek contains saponins, hemicelluloses, mucilage, tannins and pectin and these compounds help to decrease the level of low density lipoprotein-cholesterol (LDL) in blood by inhibiting bile salts re-absorption in the colon. Following are the advantages of fibre present in fenugreek seed:

a. It binds to toxins in the food and helps to protect the colon mucous membrane from cancer causing toxins.

b. It has been established that the amino-acid, 4-hydroxyisoleucine present in the fenugreek seed has facilitator action on insulin secretion.

c. Fibre helps to lower rate of glucose absorption in the intestines controlling blood sugar levels.

d. The higher content of soluble fibre in fenugreek enhances its strength for glucose level tolerance.

Fenugreek seeds are rich in carbohydrates and especially mucilaginous fibre which is comprised of galactomannans. The ability of fenugreek to improve glucose tolerance is further enhanced by its rich content of soluble fibre (Table 4).

Galactomannan is a major soluble fibre of the fenugreek seeds; it decreases the bile salts uptake in intestine and also reduces the digestion and absorption of starch in body [28].

Mathen et al. [29] has made studies on trend of food consumption in obese human beings and found that fenugreek fibre significantly increased satiety and reduced energy intake at lunch, suggesting that it may have short-term beneficial effects in obese subjects. Naidu et al. (2011) [30] reported that fenugreek husk is a valuable source of dietary fiber and phenolic acids; therefore, it could be an effective source of natural antioxidants and natural ingredients in functional foods.

Alkaloid, flavonoids and saponin in fenugreek

Fenugreek contains different alkaloids, flavonoids and saponins [31-33] but out of all these, saponins are found to be in maximum concentration in the fenugreek [34]. Alkaloid is natural bases containing at least one nitrogen atom in its heterocyclic ring and is found in plants [31]. Alkaloid and volatiles of fenugreek seed are two major constituents which causes bitter taste and bad odour due to which people try to avoid consumption of fenugreek seed and its products [35]. Fenugreek contains 35% alkaloids, primarily trigonelline [36], whereas saponin was found to be 4.8% [14,37]. One hundred gram of Fenugreek endosperm is reported to be containing 4.63 g saponin. The alkaloids, flavonoids and saponins of fenugreek have pharmacological effect. They act as antilipidemic, hypoglycaemic and cholagogic agent and their use should be promoted to manage diabetes mellitus, hypercholesterolemia because clinical evidence shows promising results in reducing serum cholesterol level. At the same time, care should be taken to avoid minor gastrointestinal symptoms and allergic reactions on its consumption [38]. Murlidhara et al. [14] however, considered alkaloid and saponins as anti-nutritional factors in human food though the extract of fenugreek containing saponins is found to be 4.8% [14,37]. One hundred gram of Fenugreek endosperm is reported to be containing 4.63 g saponin. The alkaloids, flavonoids and saponins of fenugreek have pharmacological effect. They act as antilipidemic, hypoglycaemic and cholagogic agent and their use should be promoted to manage diabetes mellitus, hypercholesterolemia because clinical evidence shows promising results in reducing serum cholesterol level. At the same time, care should be taken to avoid minor gastrointestinal symptoms and allergic reactions on its consumption [38]. Murlidhara et al. [14] however, considered alkaloid and saponins as anti-nutritional factors in human food though the extract of fenugreek containing saponins is found to be enhancing hunger, reducing plasma cholesterol level and hypcholesterolemia in rats [39]. Fenugreek also contains flavonoid more than 100 mg per g of seed [40].

Protein in fenugreek

Fenugreek endosperm is rich in protein such as globulin, histidine,
References

Further to this, their results showed that fenugreek protein concentrate and measured emulsion and foaming properties are attained at pH 4.5 which is the isoelectric point of the protein. Minimum values of both emulsion and foam properties and showed that they are greatly affected by pH levels and salt (NaCl) concentration. Nasri and Tinay [42] studied functional properties of fenugreek seed powder is allergic and potentially cross-reactive with peanut to lists of ingredients. However, it should be warned that fenugreek for sensitization and provocation of allergic incidents are probably low. Therefore, the food manufacturers should consider adding fenugreek proteinaceous matter does not have any significant effect on the surface activity of the fenugreek gum. Youssef et al. [20] reported that residual proteins played an important role in decreasing the tension at the oil-water interface. The molecular weight of fenugreek gum is increased by removing the attached proteins. Viscosity of fenugreek gum increases with increasing gum concentration or with reduction of the residual protein attached.

Interestingly, studies concluded so far [36] reveal that considering the relatively low levels of spices that are added to foods, the thresholds for sensitization and provocation of allergic incidents are probably low. Therefore, the food manufacturers should consider adding fenugreek to lists of ingredients. However, it should be warned that fenugreek seed powder is allergic and potentially cross-reactive with peanut allergens. This may be why the consumption of fenugreek containing foods represents a risk for persons having peanut allergy. It is also to be noted that digestibility in rat has decreased with increasing protein and dry matter of fenugreek seed in their diet. This indicates that a judicious use of fenugreek seed in diet may be helpful for those who have no symptoms of allergy as such.

Nasri and Tinay [42] studied functional properties of fenugreek protein concentrate and measured emulsion and foaming properties and showed that they are greatly affected by pH levels and salt (NaCl) concentration. Minimum values of both emulsion and foam properties are attained at pH 4.5 which is the isoelectric point of the protein. Further to this, their results showed that fenugreek protein concentrate has high oil absorption capacity (1.56 ml oil per g protein), water absorption capacity (1.68 ml H₂O per g protein) and bulk density (0.66 g per ml). The protein of fenugreek seeds is found to be more soluble (18.5%, 91.3%) at acidic (4.5) and alkaline (11) pH respectively than at nearly neutral pH. The gums containing high protein show the ability to decrease the surface tension of water. However, it is also indicated that removal of proteins by an enzyme protease affected the surface activity of fenugreek gum. Hence, enzymatic removal of protein reduces the ability of fenugreek gum to reduce the interfacial tension [22]. In another study on fenugreek protein, Srinivasan (2006) [43] reported that cooking does not affect the quality of fenugreek seed proteins. It is evidenced in the animal study that the replacement of casein diet up to 10% by fenugreek seeds did not produce any harmful effect in protein quality of casein as studies on animal subjects has been evidenced for protein efficiency ratio, protein digestibility and net protein utilization [25]. However, debittered fenugreek seeds are rich in protein and lysine [12].

Vitamins in fenugreek

Fenugreek is especially rich in choline [12]. Vitamins - A (1040 IU per 100 g), B₁ (0.41 mg per 100 g), B₂ (0.36 mg per 100 g), C (12.0 mg per 100 g), niacin (6.0 mg per 100 g) and nicotinic acid (1.1 mg per 100 g) are reported in fenugreek seed where as germinating seeds contain pyridoxine, cyanocobalamin, calcium pantothenate, biotin and vitamin C [44]. Fenugreek leaves contain Vitamin C (43.10 mg per 100 g), calcium, β-carotene but by boiling in water, or steaming and frying, the vegetable loses 10.8 and 7.4% of the vitamin, respectively and exposure of the germinating seeds to β- and γ-radiation reduces the vitamin C content. Srinivasan (2006) [6] reported vitamin C, β-carotene, thiamine, riboflavin, nicotinic acid, folic acid as contents as 52 mg, 2.3 mg, 40 μg, 310 μg, 800 μg, 0 μm in leaves and 43 mg, 96 μg, 340 μg, 290 μg, 1.1 mg, 84 μg in seeds respectively. Poole et al. [45] showed that fenugreek consumption has potentially improved body composition in particular body fat percentage and vitamin C of fenugreek seed has an important role.

Minerals in fenugreek

Fenugreek does not contain so many minerals but it has some of them such as it has good amount of phosphorus and sulphur [42]. Jani et al. (2009) [46] has reported higher occurrence of calcium, iron and zinc in curry made from fenugreek compared to the curry made from potato.

Grinding of fenugreek

To preserve the volatile and aroma content and also to take care of protein content of fenugreek in processes such as grinding, one can opt for cryogenic grinding because of its beneficial effects as mentioned in the flow chart (Figure 1).

Medical Uses of Fenugreek

Anticarcinogenic activities and complementary cancer therapy

Fenugreek is a promising protective medicinal herb for complementary therapy in cancer patients under chemotherapeutic interventions because fenugreek extract shows a protective effect by modifying the cyclophosphamide induced apoptosis and free radical-mediated lipid peroxidation in the urinary bladder of mice [47]. Diosgenin (C₂₇H₄₈O₃) is a crystalline steroid sapogenin found in fenugreek and used as a starting material for the synthesis of steroid hormones such as cortisone and progesterone. It has been found to be potentially important in treatment cancer [48]. It has the ability to prevent invasion, suppress proliferation and osteoclastogenesis.
through inhibition of necrosis factor NF-kappa B-regulated gene expression and enhances apoptosis induced by cytokines and chemotherapeutic agents [49]. The seed powder in the diet due to the presence of fibre, flavonoids and saponins decreased the activity of β-glucoronidase significantly and prevented the free carcinogens from acting on colonocytes whereas mucinase helped in hydrolysing the protective mucin.

Sur et al. [50] found that intra-peritoneal administration of the alcohol seed extract before and after inoculation of Ehrlich ascites carcinoma cell in mice prevented tumor cell growth and this treatment enhanced peritoneal exudates and macrophage cell counts. Protodioscin of fenugreek exhibited a strong inhibitory effect against leukemic cell line HL-60 and a weak growth inhibitory effect on gastric cell line KATO-III [51]. Diosgenin in fenugreek prevented cell growth and induced apoptosis in the H-29 human colon cancer cell line [52] and fenugreek seed was found to have hepatoprotective properties [53]. Kaviarasan and Anuradha [54] concluded that polyphenolic extract of fenugreek seed acts as a protective agent against ethanol induced abnormalities in the liver having similar affects as that of silymarin, a known hepatoprotective agent.

**Hypocholesterolemic activities**

The abnormal deficiency of cholesterol level in the blood is known as hypocholesterolemic problem and oral administration of methanolic and aqueous extracts of seeds at a dose of one gram per kilogram body weight resulted in hypoglycaemic effect in mice [55]. Singhal et al. [56] showed hypocholesterolemic effects of fenugreek seeds and [57] reported that fenugreek seeds have lowered serum cholesterol, triglyceride and low-density lipoprotein in hypercholesterolema suffering patients and experimental models. Fenugreek consumption in diet reduced triglyceride accumulation in the liver but do not interfered with the plasma insulin or glucose levels obesity suffering rats [57].

**Hypoglycemic activities**

Hypoglycemia is a condition of human body in which there is an abnormal decrease in the sugar level of the blood. Singh and Garg (2006) [58] reported that fenugreek seeds have hypoglycemic and hypocholesterolemic effect as supported by findings during the experiment on animals. It improves peripheral glucose utilization, contributing to improvement in glucose tolerance and exerts its hypoglycemic effect by acting at the insulin receptor level as well as at the gastrointestinal level. Raghuuram et al. (1994) [59] reported increased erythrocyte insulin reception due to fenugreek consumption and they concluded with the help of intravenous glucose tolerance test that fenugreek in the diet reduced the area under the plasma glucose curve significantly and shortened the half-life of plasma glucose by the increased metabolic clearance.

Sharma (1986) [13] reported that injection of fenugreek seed powder improved plasma glucose and insulin responses and reduced urinary concentrations. Daily administration of 25 g fenugreek seed powder in diabetic insulin suffering patient resulted fasting plasma glucose profile, glycosuria and daily insulin requirement (56 to 20 units) and resulted in significant reductions in serum cholesterol concentrations [13]. The post-prandial blood glucose levels in targeted subjects were reduced significantly by giving raw and germinated fenugreek compared to those without fenugreek or boiled fenugreek [60].

**Antioxidant**

Fenugreek contains phenolic and flavonoid compounds which help to enhance its antioxidant capacity [61]. Table 5 shows the major medicinal and general uses and application of the fenugreek.

Balch [7] 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. An aqueous fraction of fenugreek exhibits the highest antioxidant activity compared to other fractions and the quantity of phenolic and flavonoid compounds are related to antioxidant activity. These studies reveal significant antioxidant activity in germinated fenugreek seeds which may be due to the presence of flavonoids and polyphenols. Furthermore, Grover et al. (2002) [62] reported that mustard and fenugreek seeds showed hypoglycemic and antihyperglycemic activity in diabetic mice and they have attributed that the health benefits may be due to the presence of antioxidant carotenoids in those spices.

**Influence on enzymatic activities**

Several researchers as mentioned in [63,64] and [28] have shown in human subject and animal models that fenugreek has the ability to some extent to restore the actions of key enzymes in particular lipids and carbohydrates. Baquer et al. (2011) [65] reported that trigonella administration in rats restored the changed enzyme activities and partially normalized hyperglycemia. Concluded from their experiments that the altered levels of superoxide dismutate, antioxidant enzymes catalase and glutathione peroxidase in liver and kidney of diabetic rats were corrected by treating with insulin, vanadate, fenugreek and the combined dose of vanadate and fenugreek. It showed that the activities of glucose-6-phosphatase and fructose-1, 6-biphosphatase in the liver and kidneys of diabetic rats are reduced by administration of fenugreek.

The α-galactosidase enzyme of germinated fenugreek seeds act on galactomannan to convert it into galactose [66]. Giving of fenugreek seed polyphenol per day that reduced the levels of lipid peroxidation products and protein carbonyl content. On the other hand, it promoted...
| S. No. | Application of fenugreek                                      | Responsible component of fenugreek | References |
|-------|---------------------------------------------------------------|-----------------------------------|------------|
|       | **General uses of fenugreek**                                |                                   |            |
| 1.    | Culinary (colour, flavour, aroma)                            | Seed, leaves                       | 23         |
| 2     | Vegetable                                                    | Leaves and seeds                   | 7          |
| 3     | Ingredients in bread making with maize and wheat flour       | Seeds                             | 8          |
| 4     | Forage                                                       | Leaves, straws, immature seeds (proteins, vitamins, carbohydrates) | 3          |
| 5     | Spice and seasoning                                          | Leaves and seeds                   | 6, 3       |
| 6     | Cosmetics                                                    | Seeds, leaves                      | 2          |
| 7     | Paints                                                       | Seeds, leaves                      | 2          |
| 8     | Paper industries                                             | Leaves, seeds                      | 2          |
| 9     | Organoletic character improver                               | Seeds, leaves                      | 6          |
| 10    | Maple syrup and artificial flavouring                        | Trigonelline                       | 2          |
| 11    | Holy fumigants & embalming rites                             | Smoke of fenugreek leaves          | 26         |
| 12    | Food                                                         | Mixed with flour for bread, yellow dye | 6          |
| 13    | Functional food                                              | Dietary fibre, galactomannan       | 2          |
| 14    | Flavouring                                                   | Curries, condiments, pickles, chutneys | 6          |
| 15    | Colouring dye                                                | Seeds                              | 2          |
| 16    | Food Gum                                                     | Seed                               | 18         |
| 17    | Fenugreek as a food stabilizer, adhesive and emulsifying agent | Seed                               | 14, 3      |
| 18    | Perfume                                                      | Fenugreek oil                      | 6          |
| 19    | Insect repellent                                             | Fenugreek oil                      | 26         |
| 20    | Alcoholic beverages and perfumery                            | Seeds                              | 14         |
| 21    | Bread-making along with wheat and maize flour                | Seeds                              | 27, 28     |
|       | **Medicinal uses of fenugreek**                              |                                   |            |
| 1     | Reduces the sugar level of the blood                         | Seeds                              | 10         |
| 2     | Reduces perspiration, fever, allergies, bronchitis and congestion | Seeds, leaves                       | 82         |
| 4     | Helps in loosening excess mucus and phlegm                   | Seeds, leaves                      | 62         |
| 5     | Treats sinus and lung congestion                            | Seed                               | 56         |
| 6     | Acts as anti-infection agent                                 | Seeds, leaves                      | 18         |
| 7     | Reduces congestion                                           | Seed                               | 10         |
| 8     | Lowers blood pressure                                        | Seeds and leaves                   | 3          |
| 9     | Carminative flatulence (prevents gas formation in digestive tract) | Seed and leaves                    | 29         |
| 3     | Aphrodisiac                                                  | Seed leaves                        | 28         |
| 4     | Pharmaceutical (raw material for hormones and therapeutic drugs) | Steroids, flavonoids, alkaloids   | 2          |
| 5     | Wounds and sore muscles treatment                            | Seeds and leaves                   | 29         |
| 6     | Anti-bacterial agent                                         | Seeds and leaves                   | 3          |
| 7     | Anti-cancer agent                                            | Seeds, leaves                      | 3, 29      |
| 8     | Anti-ulcer agent                                             | Seeds leaves                       | 3          |
| 9     | Anti-nociceptive (Pain reducing)                             | Seeds leaves                       | 30         |
| 10    | Anthelmintic agent                                           | Seeds and leaves                   | 31         |
| 11    | Induces labor during child birth and delivery                | Seed                               | 30         |
| 12    | Induces growth and reproduction hormones                     | Diogenin hormones                  | 2          |
| 13    | For immunomodulatory function                               | Hormones                           | 29, 3      |
| 14    | Hypocholesterolemic                                          | Whole fenugreek seed               | 9, 3       |
| 15    | Hypoglycemic                                                 | Methanolic and aqueous extracts of seeds | 32         |
| 16    | Gastro- and hepatoprotective                                 | Leaves and seeds                   | 2          |
| 17    | Antioxidant                                                  | Seed, leaves                       | 33         |
| 18    | Diabetes management                                          | Seed                               |            |
| 19    | Cardiovascular health                                        | Bioactive compound                 | 2          |
| 20    | Hair strengthening agent                                     | Fresh leaves, fenugreek seed       | 33         |
| 21    | Prevents constipation                                        | Seed                               |            |
| 22    | Improves digestion                                           | Seed, leaves                       | 3          |
| 23    | Stimulates liver and spleen                                  | Seed, leaves                       |            |
| 24    | Purifies blood                                               | Seed, leaves                       | 3          |
| 25    | Serves as appetizer                                          | Seed, leaves                       |            |
| 26    | Poultice for ulcers, boils and abscess                       | The twigs and leaves               |            |
| 27    | Lowering of blood cholesterol                               | Seed, leaves                       | 24         |

Table 5: Major general and medicinal uses of fenugreek.
mode of action of antioxidant enzymes, and restored content of thiol groups.

Yadav et al. [67] has exhibited that by the combined treatment of fenugreek and sodium-orthovanadate, activities of nicotinamide adenine dinucleotide phosphate-linked enzymes such as glucose-6-phosphate dehydrogenase, malic enzyme, isocitrate dehydrogenase, and the activities of lipogenic enzymes such as adenosine triphosphate-citrate lyase and fatty acid synthase were decreased significantly in liver and increased in kidney during diabetes as compared to those of control.

**Immunomodulatory effect**

An agent that intensifies or diminishes the immune responses is known as immunomodulator and such effect is called as immunomodulatory effect. Research work in this effect of fenugreek is scanty but showed stimulatory immunomodulatory effect (as evidenced from body weight, relative thymus weight, cellularity of lymphoid organs, delayed type of hypersensitivity response, plaque forming cell assay, haemagglutination titre, quantitative haemolysis assay, phagocytosis, lymph proliferation and a significant increase in phagocytic index and phagocytic capacity of macrophages) of aqueous extract of fenugreek at three doses 50, 100 and 200 mg per kg of body weight for 10 days on the immune system of Swiss albino mice.

**Antifertility effect**

Evaluated the potential antifertility activity of feeding diets containing 30% fenugreek seeds to male and female white rabbits of New Zealand and reported the following results: a) an antifertility effect of fenugreek seed in female rabbit; b) toxicity effect in male rabbit; c) testis weight in male reduced with damage to the seminiferous tubules and interstitial tissues; d) in the treated animals, the plasma concentration of the androgen hormone and sperm concentrations were halved; f) in the females rabbits, significant reduction of developing foetuses and g) in the treated animals, the circulation of plasma progesterone weight for 10 days on the immune system of Swiss albino mice.

**Diabetes management**

Das et al. [69] has reported that 25-50 g fenugreek seeds were given to diabetic patients daily in diet to prevent and manage long term complications of diabetes whereas studies have been made about the glycemic index of fenugreek recipes and found that the soluble fenugreek fibre has significantly reduced the glycemic index [18] and therefore, they recommended the inclusion of fenugreek recipes in daily diet to provide at least 25 g fenugreek seeds that helps in diabetes management. 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. Since fenugreek seeds are a source of protein, they can replace pulses in the diets of diabetics. 25-50 g fenugreek in the diet of diabetic patients increases the hypoglycemic and antihyperglycemic potential and for this reason it may be used as a supplementary medicine to treat diabetes patients.

In type-1 diabetic rats, administration of fenugreek and sodium-orthovanadate orally [71] concluded that sodium-orthovanadate and fenugreek administration to diabetic animals prevent development of hyperglycemia and alteration in lipid profile in plasma and tissues and maintain it near normal but maximum prevention can be observed in the combined treatment with lower dose of sodium-orthovanadate, whereas in another studies, in mild type-2 diabetic patients adjunct use of fenugreek seeds found to improve glycemic control and decrease insulin resistance [72]. Kocchar and Nigam [73] concluded that 2 g of a powdered assortment of bittergourd, jamun seed and fenugreek seed, either raw or cooked, can be used successfully. Studies of [74] on mechanism of anti-diabetic action, efficacy and safety profile of GII (anti-hyperglycemic compound) purified from fenugreek seeds in sub-diabetic and moderately diabetic rabbits shows that GII seems to decrease lipid content of liver and stimulate the enzymes of glycolysis and inhibit enzymes of gluconeogenesis in the liver of diabetics, especially moderately diabetic rabbits. 4-hydroxyisoleucine is a type of isomer, an atypical branched-chain amino acid, found in fenugreek has effect on glucose and lipid metabolism and can be used for control of type-II diabetes, obesity and dyslipidemia, because it has been clinically evidenced that 4-hydroxyisoleucine stimulates glucose-dependent insulin secretion, decreases insulin resistance in muscles and liver by activating insulin receptor substrate-associated phosphoinositide 3-kinase activity, reduces body weight (plasma insulin and glucose levels) in diet-induced obese mice and decreases elevated plasma triglyceride and total cholesterol levels in hamster model of diabetes [75].

Kariarasan et al. (2009) [76] concluded that ethanol-induced liver cell damage can be protected by cytoprotective action of fenugreek seed polyphenolic extract possibly due to its enhancing cellular redox status. Fenugreek reduced significantly the blood sugar in fasting and post prandial subjects but it did not affect platelet aggregation, fibrinolytic activity and fibrinogen [77].

**Antilulcer**

The aqueous extract and a gel fraction, isolated from the seeds showed significant ulcer protective effects. It has soothing effect on gastric and gastritis ulcer [6].

**Beneficial Influence of Fenugreek on Digestion**

Spices consumed in diet positively influenced the pancreatic digestive enzymes. Platel and Srinivasan [78] experimentally showed that dietary curcumin, capsacin, Piperine, ginger, fenugreek and asafoetida prominently enhanced pancreatic lipase activity with the help of feeding rats with spicy diets for eight weeks.

Non-starchy polysaccharides increase the bulk of the food and augments bowel movements. Also, non-starchy polysaccharides assist in smooth digestion whereas high fibre of fenugreek helps in relieving constipation ailments.

**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 [79] 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 comparable 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. The solubility and emulsifying properties of soy protein isolate with fenugreek gum dispersions were also stable over wide range of pH, ion strength and high temperature. The higher dietary fibre content of fenugreek acts as probiotic in functional food [9]. Sowmya and Rajyalakshmi (1999) [19] reported that the soluble fibre of fenugreek acts as an excellent substrate for fermentation done by the microorganisms in the large intestine. Garti et al (1997) [26] demonstrated that fenugreek gum shows an emulsifying capability for stabilizing oil-in-water emulsions and they further concluded from their study that critical coverage of gum/oil ratio for stable non-coalesced emulsion was smaller than the ratio obtained for guar or other gum, indicating its emulsification properties to be superior to those of other galactomannans. Fenugreek gum has very good application in making soups because it modifies the rheological properties and interaction of starch and other soup ingredients.

Losso et al. [80] incorporated fenugreek in bread making and demonstrated that fenugreek in food helps to reduce blood sugar but use of fenugreek is a barrier due to its bitter taste and strong odd flavor. They did not find significant variation 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. Bread maintained fenugreek’s functional property of reducing insulin resistance. 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 diabetes patients as well.

Fenugreek in traditional food

Fenugreek paste, locally termed as “Cemen” is a popular food in Turkey [23], which is prepared from ground fenugreek seeds. Crushed fenugreek seed or coarse fenugreek powder is used to make ball for making of clarified butter.

Other benefits, beneficial uses and application of fenugreek

Fenugreek has the ability to lower the hepatic lipids in body because of its potential to modify the activities of several enzymes such as enzymes related to glucose and lipid metabolism [28]. Fenugreek is anthelmintic (ability to cause the evacuation of parasitic intestinal worms) in nature. As fenugreek has a high fibre content, which helps in controlling cholesterol in human body, it takes care of some of the problems related to heart. It is diuretic emmenagogue, emollient in nature and controls heart diseases.

Care, Concern and Safety in Fenugreek Use

Muralidhara et al. [14] investigated toxic effects of debittered fenugreek powder on acute and subchronic regimes in mice and rats, and could not find any sign of toxicity, mortality, change in body weight, organ weight; up to a maximum dosage of 2.5 g per kg body weight of mice and rat. Even though there is no toxic or any other side effect of consuming fenugreek even up to 20% level by both the normal as well as diabetic people [38], food safety is an important issue and is crucial now-a-days because people are very much conscious for their health. Therefore, one should be aware of the fact that how much, in what way, at what time, and in which condition, fenugreek should be used. Food quality and safety of fenugreek is determined by its production practices, handling, preparation and storage. Table 6 shows some of the problems associated with processing and consumption of fenugreek. Food quality and safety has high significance in expanding global food trade [81]. It should be used in minute quantity. Diabetic patients should avoid its use along with therapeutic medication because fenugreek could interfere with the absorption of those therapies that control blood sugar. It should not be consumed in excess amount because it has high content of fibre which may cause problem with digestion. There is a problem of odd smelling in sweet after consuming fenugreek, hence it should be used in limited quantity.

Faeste et al. (2009) [82] has established significant homologies to major peanut allergens that can explain the proliferation of secondary fenugreek allergy due to cross-reactivity in peanut allergic patients. The application of vanadium alone in rats created toxicity but was nullified when fenugreek powder was given.

When fenugreek paste was applied to a scalp as a treatment for dandruff, it resulted in numbness of head, facial angioedema, and

| S.No. | Problem of fenugreek consumption | Cause/Effect | Reference |
|-------|---------------------------------|-------------|-----------|
| 1     | Decrease in body weight and T3 (Thyroid hormone) | It has less fat and nutritive value whereas it acts as bulk in intestine | 35 |
| 2     | Interfere with the absorption of oral medication | Rich in fibre | 35 |
| 3     | Produces an unwanted odd smell | Excess consumption of fenugreek seed and fresh leaves | 107 |
| 4     | Stomach pain | Excess eating, has high fibre content (can’t be easily digested) | 38, 39 |
| 5     | Hypoglycemic agents, lower serum glucose level | Due to anti-diabetic nature | 38, 39 |

Problems in the processing of fenugreek

| S.No. | Problem of fenugreek consumption | Cause/Effect | Reference |
|-------|---------------------------------|-------------|-----------|
| 1     | On increasing pH | Antioxidant properties decrease | 36 |
| 2     | Ambient grinding | Loss of flavour, aroma and protein | 26 |
| 3     | Drying of fenugreek at high temperature (seed, leaves) | Loss of β-carotene, ascorbic acid, chlorophyll content | 37, 25 |
| 4     | During grinding sticks to the grinder’s wheels | Due to gummy and sticky nature; Leads to choking | 26 |

Table 6: Problems associated with the use and processing of fenugreek.
wheezing so, it evidenced strong sensitivity to fenugreek in patients but controls did not show such response with fenugreek extract [8].

Conclusion

The major health beneficial properties of fenugreek, which can give promising therapeutic application, found in various studies in last three decades has been discussed in this review article. Antidiabetic, antioxidant, anticarcinogenic, anthelmintic, antiulcer, antifertility, immunomodulatory effect, enzymatic pathway modifier, hypoglycemic activity, hypocholesterolemic activity are the major medicinal properties of the fenugreek demonstrated in various studies. High fibre content, protein content, gummy nature and other bioactive compounds make it a naturally several health promoting herb. Based on the these several medicinal usefulness as discussed based on various past reported scientific findings, fenugreek can be recommended and can be made a part of our daily diet as its liberal use is safe and various health benefit can be drawn from this natural herb but in some extreme cases like patient suffering from chronic asthma etc., it should be avoided or its consumption should be minimized.

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