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Functional properties and food applications of fenugreek - A review

Abstract

Fenugreek (*Trigonella foenum-graecum*) is a legume which is rich in protein, minerals, vitamins and phytonutrients (alkaloids, including carpaine, gentianine and trigonelline). Fenugreek has medicinal and therapeutic properties like anti-cancer, gastroprotective, anti-obesity, antifungal–antimicrobial, cardiac protective, cholesterol-lowering agent, anti-carcinogenic and antidiabetic properties. In addition, it also functions in lowering the blood sugar level, improving insulin sensitivity as well as sexual function and also acts in detoxification of the body. Moreover, the flavonoids and phenolic compounds found in fenugreek helps to enhance its antioxidant capacity and have a positive impact on the pancreas and liver because antioxidant properties have been connected to the health advantages of natural foods. Fenugreek also have strong antifungal and antimicrobial properties. Furthermore, fenugreek seeds have bitter taste and a maple flavour when raw, however, by roasting and germination, the bitterness can be lowered and its flavour can be improved. It has been historically used as a spice and herb to enhance the flavour, texture and colour of many food products. The fenugreek hydrocolloid, specifically fenugreek gum (soluble fibre), has the capability to emulsify, thicken, stabilize, gel and encapsulate substances. Consequently, dietary fiber, particularly soluble fiber, had made its way into dairy products, cereal bars and nutritional drinks.

Key Words: fenugreek, therapeutic, food, milk, antioxidant, antimicrobial

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Introduction

Leguminosae is a family of legumes that includes fenugreek (*Trigonella foenum-graecum*), which is generally referred to as '*Methi*' in India and is typically grown in Middle Eastern nations including Egypt, Pakistan, and India.[1] It has various names in different languages, such as *Methi*, *Methika* (Hindi), *Bockshorklee*, *Bockshornsamen-seed* (German), *Fenugrec, Trigonelle* (French), *Fieno greco* (Italian), *Fenogreco*, *Alholva* (Spanish), *Pazhitnik grecheskiy*, *Pazhitnik* (Russian), *Halba* (Malaya), *Koroha* (Japanese), *Fenegriek* (Dutch), *K'u-Tou* (China), and *Alforva*, *Feno-grego* (Portuguese), *Hulba* (Arabian).[2-4] It is used as a condiment for flavouring of foods. It has got medicinal value, hence used as medicine.[5] Its seed is famous for being mildly sweet and somewhat bitter in taste. A corneous and fairly big, white and semi-transparent endosperm surrounds the center hard and yellow embryo in fenugreek seeds.[6] Fenugreek contains (58%) carbohydrates in which the dietary fiber is nearly (25%), (23–26%) protein and (6–7%) fat. Fenugreek has a higher content of iron, i.e. 33 mg/100 g.[7]

Fenugreek seeds have bitter taste and a maple flavour when they are raw, however, by roasting and germination, the bitterness can be lowered and its own flavour can be improved. In pickles, vegetable dishes and spice powder the entire seeds or pulverized powder from the fenugreek seeds are used. Dried seeds are used as a food additive. The seeds of fenugreek have a fibrous, gummy and sticky texture. Biologically, their seeds are endospermic in nature.[8] As a legume, fenugreek seeds are rich in proteins and are also rich in minerals, vitamins and phytonutrients. Also, the fenugreek seeds are very good source of soluble dietary fiber. About 100 g of seeds gives 24.6 g or more dietary fiber.[9]

Due to fenugreeks high protein, fibre and gum content, fenugreek is now employed as an emulsifying agent, food stabilizer and glue. It has been historically used as a spice and herb to enhance the flavour, texture and colour of food products.[8] In addition, fenugreek seeds contain significant amount of glycolipids, phospholipids, linolenic acid, oleic acid and linoleic acid as well as retinol, choline, thiamine, riboflavin, ascorbic acid, niacin and nicotinic acid.[10-12]

Chemical compounds in fenugreek

The Table 1 lists the relative amounts of flavonoids, saponins and alkaloids found in fenugreek.[8,11,13,14,15] The two main chemical components of fenugreek seed that gives bitter flavour are alkaloids and volatiles, 35% of the alkaloids in fenugreek endosperm are trigonelline. According to Naidu et al.[16], fenugreek seed contains more than 100 mg/g of flavonoid. All of these substances are categorized as biologically active because they exert pharmacologic effects on human body. To cure cancer, hypercholesterolemia and diabetes mellitus, their inclusion in the daily diet should be encouraged because of their cholagogic, antilipidemic, hypoglycemic and anticarcinogenic properties (**Table 1**).[8]

Flavour compounds present in fenugreek

Glycoside, isoorientin, orientin, epigenin, vitexin and quercetin are the primary flavonoids found in fenugreek.[1] Alkaloids and a few other volatile chemicals give fenugreek its unique bitter flavour and odour.[17] Fenugreek seeds contain small amount of volatile oils.[13] Based on the fenugreek aroma detection using gas chromatography, the odour-active components were investigated and it was found that they contained substances such as olfactometry diacetyl, acetic acid, sotolon, 1-octene-3-one isovaleric acid, butanoic acid and 3-isobutyl-2-methoxypyrazine caproic acid, eugenol and 3-isopropyl, 4-dihydro-2(5H)-furanone, 3-amino-4,5-dimethyl-3-linalool 5-octadiene-3-one and 2-methoxypyrazine (Z)-1 have distinct aromas that are paprika-like, metallic, roasty/earthy, floral, musty and spicy, respectively. Out of all of these volatile substances, sotolon (Figure 1) was shown to be present in fenugreek most frequently in (5s)-enantiomeric form

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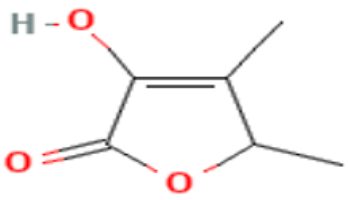
(95%).[7,18] Numerous coumarin chemicals, as well as a variety of alkaloids, including carpaine, gentianine and trigonelline, have been identified in fenugreek seeds. Trigonelline is extensively converted to nicotinic acid in the body. According to He et al.[19] polyphenolic chemicals such diosgenin, isovitexin and rhaponticin are thought to be the main bioactive components in fenugreek seeds (Figure 1).

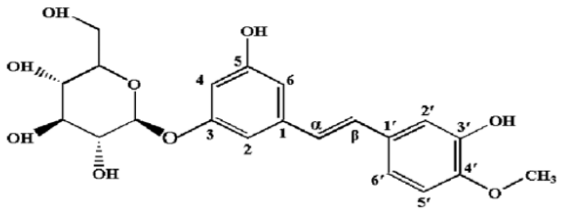
Table 1 Alkaloids, flavonoids and saponin of fenugreek seeds and their classification

Chemical group	Compounds
Alkaloids	Trimethylamine, trigonelline, carpaine, choline
Amino acids	Histidine, arginine, isoleucine, leucine, 4-hydroxyisoleucine, lysine, L- tryptophan
Flavonoids	Saponaretin, lilyn, tricin 7-O-D glucopyranoside, naringenin, kaempferol, isovitexin & isoorientin, vitexin, luteolin, quercetin, orientin and vitexin
Saponins	Fenugrin B, graecunins, fenugreekine, trigofoenosides A-G, glycoside, trigonoesides, smilagenin, gitogenin, sarsasapogenin, yuccagenin, hederagin, diosgenin, tigonenin and neotigogenin
Steroidal	Diosgenin, yamogenin, smilagenin
Sapinogens	Yuccagenin, saponaretin, sarsasapogenin, tigogenin, neotigogenin, gitogenin and neogitogenin
Fibers	Gum, neutral detergent fiber
Lipids	Free fatty acids, phosphatidylethanolamine, phosphatidylcholine, phosphatidylinositol, monoacylglycerols, triacylglycerols
Other	Vitamins, minerals, lipids and coumarin. Proteins make up 22%, mucilage 28% and a greater swelling, bitter fixed oil 5%

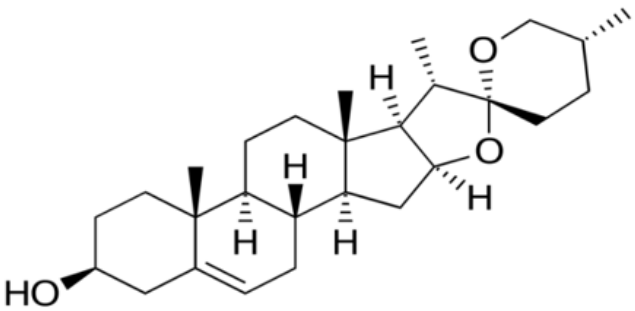
1. Sotolon



2. Diosgenin



3. Rhaponticin



4. Isovitexin

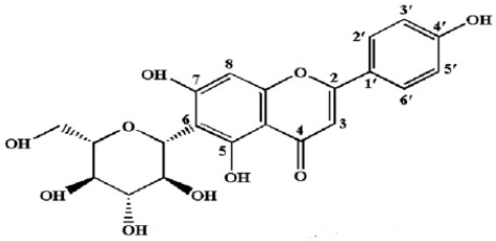


Figure 1 Chemical structure of (1) Sotolon, (2) Diosgenin, (3) Rhaponticin and (4) Isovitexin.

Uses of fenugreek

Medicinal and therapeutic properties: Fenugreek (*Trigonella foenum-graecum*) is an herb that has therapeutic properties. It is used to increase milk flow in women to ease child growth.[20] *Methi* tea with honey and lemon is used to treat fever and is also used as a home medicine for burns, gout and eczema in India.[21] Since ancient times, *K'u-Tou* (China) (fenugreek) is used as traditional Chinese medicine for the treatment (nurcing) of leg oedema and weakness and its liquid tonics are used as medicine.[22] Fenugreek has also been used for influenza, asthma, catarrh, bronchial complaints, constipation, sinusitis, relieving colds, pleurisy, laryngitis, sore throat, pneumonia, emphysema and hay fever tuberculosis.[23] The presence of phenolic and flavonoids in fenugreek has a positive effect on the pancreas and liver whereas in red blood cells, fenugreek inhibits lipid peroxidation.[24]

Fenugreek seeds have been shown to lower blood sugar levels and improve insulin sensitivity. Trigonellin, an alkaloid found in fenugreek seed has anti-diabetic properties because it stimulates the insulin signaling system. Another compound, galactomannan, a type of dietary fiber, present in fenugreek seeds helps diabetics to lower their blood sugar levels. In addition, fenugreek have therapeutic pharmacological functions like anti-cancer, gastroprotective, anti-obesity, antifungal–antimicrobial properties, cardiac protective, cholesterol-lowering agent, anti-carcinogenic, antidiabetic and helps in improving sexual function as well as galactogogue function.[1]

Additionally, fenugreek (*Trigonella foenum-graecum*) have a positive impact on blood purification and it also helps in detoxification of the body. Although its essential function is to irrigate the cells with nutrients and eliminate harmful wastes, dead cells and stuck proteins

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from the body, fenugreek is well known for its lymphatic cleansing activity. A block in the lymphatic system in the body of a person can result in poor fluid retention, pain, disease, energy loss fluid and circulation. By aiding in the clearing of congestion, fenugreek helps to maintain mucus conditions in the body, particularly the lungs. It also acts as a mucus solvent and throat cleaner, which eases the urge to cough. The masses of cellular waste can be softened and dissolved, accumulated and hardened by drinking water that has fenugreek seeds soaked in it. Bronchial problems, colds, influenza, catarrh, asthma, constipation, pleurisy, sinusitis, pneumonia, laryngitis, sore throat, hay fever, emphysema and tuberculosis have all been treated with fenugreek (Table 2).[2,24-29]

Table 2 Pharmacological and therapeutic benefits of fenugreek

Disorder/Disease	Description
Anemia	Prevents the oxidation of red blood cells
Aging	Antioxidants enhance ageing and cell death reduction
Cancer	Seed polyphenolic chemicals have anti-carcinogenic properties
Diabetes	The amino acid 4-hydroxy isoleucine promotes the synthesis of insulin, which lowers blood sugar levels. Polyphenolic substances have anti-diabetic properties. Fenugreek seed powder has the potential as a neuropathy treatment for diabetes
Hypercholesterolemia	Seed antioxidants lower excessive blood cholesterol
Immunodeficiency	Natural antioxidants have immune system-strengthening, immunological-modulating and immune-stimulating actions
Indigestion and flatulence	Fenugreek increases hunger and also have laxative properties
Inflammation	Reduces pain and swelling
Kidney disorders	Protects kidney problems in diabetes patients, both functionally and histopathologically. Decreases the amount of catalase (CAT) and superoxide dismutase (SOD) in patients with hypercholesterolemia. Prevent the buildup of oxidised DNA to avoid kidney damage
Others	Respiratory disorders, epilepsy, gout, chronic cough, bacterial infections, paralysis, dropsy, piles, heavy metal toxicity, liver conditions, arthritis and persistent cough

According to Moosa et al.[30], fenugreek seed powder considerably decreased serum total cholesterol, triacyl glyceride and LDL cholesterol, but it did not affect serum HDL cholesterol levels. After fenugreek was added to the rat's diet, a decrease in LDL cholesterol, total cholesterol, blood sugar and triglyceride levels was recorded. Rats blood glucose and cholesterol levels decreased more significantly when fenugreek was added to their diet.[31]

Application of fenugreek seed powder in the treatment of diabetes

Type-I diabetes: A randomised, crossover trial, including 10 patients with type-I diabetes was carried out by Sharma et al.[32] For a 10-day period (lunch and dinner), the individuals (over 25 years old) were provided with 100 g meals made from fenugreek seed powder. At the end of the trial, the fenugreek group showed considerable improvement in a number of measures, including a mean drop in fasting blood glucose levels and a mean reduction of 54% in 24-hour urine glucose levels.

Type-II diabetes: Fenugreek seeds have been showed to reduced fasting serum glucose levels in both chronic and acute conditions. The findings of a small, blinded, randomized, controlled trial was conducted to assess fenugreek seeds impact on glycemic control. Over the age of 18, 25 patients with newly discovered type 2 diabetes either received "usual care" (restriction in one's diet and exercise) or 1 g daily of a hydro-alcoholic extract of fenugreek seeds. Mean fasting blood glucose levels decreased in both groups after two months, with no discernible differences between them. At the end of the trial, mean glucose tolerance test results did not differ significantly across groups. In order to achieve glycemic control in type 2 diabetes, the study revealed that fenugreek seed extract and diet/exercise may be similarly effective methods.[33]

Role of dietary fiber: When dietary fibers are included in food systems, they offer a wide range of functional qualities. Consuming specific grains along with dietary fiber is linked to lower plasma and LDL cholesterol levels as well as a lower chance of developing serious dietary issues like obesity, diabetes, cardiovascular disease, gastrointestinal disorders, inflammatory bowel illnesses, constipation, etc.[34] In addition to these health beneficial effects, dietary fiber supplementations increase the bulk by enhancing water binding capabilities which carries economic advantages for producers as well as consumers.[35] The origin of the fibers from plants, the ratio of insoluble to soluble fiber, the fiber-fiber synergy, and interactions with other food components are all factors that affect the type and scope of the functional effects.[36] The three main processes of dietary fibers are fermentation, viscosity and bulking. Dietary fibers key effects include altering the composition of the gastrointestinal tract's contents and the way that other nutrients and substances are absorbed. In the small intestine, soluble fiber binds to bile acids to prevent them from entering the bloodstream, which decreases blood cholesterol levels. Additionally, soluble fibers slow down the absorption of sugar, lower the spike in blood sugar after eating, balance blood lipid levels and after colon fermentation, produce short chain fatty acids as a by-product with a variety of physiological functions.[37]

Fenugreek seed extracts capacity to control the digestive tracts glucose metabolism is partially attributed to its high fiber content. Due to its high fiber content, fenugreek is used as a source of natural antioxidants.[38] According to a study done on obese persons, fenugreek's dietary fiber can have positive short-term effects by decreasing energy intake and boosting satiety. According to reports, the fiber in fenugreek binds to cancer-causing chemicals in the intestine and flushes them out. It also slows down the absorption of glucose and aids in blood sugar regulation [38]. In a study it was reported that the soluble fiber fractions only selectively lower harmful triglycerides and low-density lipoproteins while maintaining healthy levels of high-density cholesterol.[39] Another research pointed out that the bacteria in the colon may digest soluble fiber to create short-chain fatty acids, which have the potential to lower cholesterol synthesis.[40]

Antioxidant properties: Fenugreek have antioxidant properties. The flavonoids and phenolic compounds found in fenugreek helps

to enhance its antioxidant capacity.[41] In a study, it was observed that the fenugreek seed extract prepared using acetone, ethanol, methanol, dichloromethane, ethyl acetate and hexane had radical scavenging activity.[42] Adegoke et al.[43] found that fenugreek seeds showed anti-hyperglycemic and hypoglycemic properties in diabetic rats, which are attributed to antioxidant chemicals found in the plant. The activity of antioxidants in fenugreek extracts was determined using β-carotene techniques. In another study, the antioxidant activity of fenugreek was reported and it was observed that at 200 µg concentrations, extracts of fenugreek husk exhibited 72%, fenugreek seed exhibited 64% and endosperm exhibited 56% antioxidant activity via free radical scavenging activity. The ability to scavenge DPPH radical by fenugreek fractions was in the order husk > full fenugreek seeds > endosperm.[16]

The increased antioxidant activity of fenugreek is attributed to its phenolic and flavonoid components. Balch[44] claimed that fenugreek has potent antioxidant qualities that have a positive impact on the pancreas and liver because antioxidant properties have been connected to the health advantages of natural foods. Studies on these features, employ fenugreek seeds that have been germinated, which are found to be more advantageous than dry seeds because they increase the bioavailability of many fenugreek elements. In the mitochondria of rat liver cells, the seed extract demonstrated hydroxyl radical scavenging and prevention of hydrogen peroxide-induced LPO. Pulse radiolysis and the deoxyribose system were used to demonstrate the extracts OH group scavenging ability. Antioxidants included in the fenugreek seed extract protects against oxidative damage to cellular components. In many model systems, the antiradical and *in-vitro* antioxidant activity of an aqueous methanolic extract of fenugreek was examined. The outcomes of several methodologies reveal certain significant variables that are accountable for the antioxidant activity of fenugreek seeds.[26] Walli et al.[45] used agar disc diffusion and agar-well diffusion methods to compare the antibacterial effects of fenugreek seeds against gram-positive and gram-negative bacteria as well as other microbes. According to the research, the antibacterial active components of fenugreek seeds are only present in the boiling water extract; both methanol and cold-water extract did not possess these components.

Antimicrobial properties: Fenugreek also have antifungal and antimicrobial properties. Many investigations and experiments have shown that fenugreek has powerful antifungal and antibacterial properties.[46] In a study, Randhir et al.[47] found that the hydro-alcoholic compounds extracted from fenugreek were high in polyphenols and flavonoids and showed antifungal activity against *Candida albicans*. Further, the ethanolic compounds extracted from fenugreek seeds inhibited both positive and negative strains of test microorganisms viz. *E. coli* and *Salmonella typhi*. Some other studies have also proven that fenugreek has antibacterial and antifungal effects. Haouala et al.[46] studied the aqueous extracts of areal parts of fenugreek plants obtained using different solvents like methanol, ethyl acetate and petroleum ether and examined its effect on the growth of fungi like *Botrytis cinerea*, *Alternaria sp*., *Rhizoctonia solani* and *Pythium aphanidermatum*. Numerous researchers have reported the efficiency of fenugreek extracts against *Helicobacter pylori*.[47-49] Mercan et al.[50] found that fenugreek plant pollen is most prevalent in honey samples with the peak antibacterial action contrary to *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* defensins are short peptides rich in cysteine and have strong antifungal properties.

A study reported that the fenugreek seed powder dramatically reduced glucuronidase activity and stopped free carcinogens from acting on colonocytes due to the fiber, flavonoids and saponins present in it, however, mucinase assisted in hydrolyzing the protective mucin. The H-29 human colon-cancer cell line was exposed to diosgenin from fenugreek, which inhibited cell growth and promoted apoptosis. Fenugreek seed was also discovered to have hepatoprotective effects.[51]

Legal status: The flavour and extract manufacturers association (FEMA No. 2485) and the council of Europe (COE No. 460) both listed fenugreek natural extracts, oleoresins and essential oils as having GRAS (generally recognized as safe) status, which is in accordance with 21 CFR 182.20. They are also included in the list of approved flavouring substances by the Council of Europe.[52]

Toxicology: Due to the significant anti-fertility and abortifacient effects of fenugreek as well as the locomotor abnormalities that were associated with its consumption in the 1960s, fenugreek toxicity was researched.[53-56] According to Ouzir et al.[57], fenugreek has a low acute hazardous potential when administered orally to mice and rats at 2 and 5 g/kg body weight and intraperitoneally at 0.65 and 3.5 g/kg body weight, respectively. Thus, it was advised that the limit should be 21g per adult person weighing 60kg in order to prevent an unintentional overdose in man and woman when administered orally.

The genetic toxicity battery test results by Flammang et al.[52] showed that fenugreek extract is completely free of any detectable genotoxic activity. Another study found no hematological abnormalities or clinical hepatic or renal damage in 60 diabetic individuals who consumed 25 g of powdered fenugreek seeds each day for 24 weeks.[32] As a result, it is anticipated that fenugreek use will be safe and its extracts may be helpful as a food product ingredient.

When powdered fenugreek seeds were given to 60 diabetic patients at a dose of 25 g per day for 24 weeks, a toxicological evaluation was performed that revealed no hematological abnormalities, clinical hepatic toxicity or renal toxicity. In a study involving animals, it was discovered that the acute oral LD50 in rats was more than 5 g/kg and the acute dermal LD50 in rabbits was more than 2 g/kg. In another experiment, mice and rats were given acute and sub-chronic doses of fenugreek powder, but neither showed any signs of toxicity nor caused any deaths. Weanling rats fed fenugreek seeds for 90 days showed no appreciable changes in their haematological, hepatic or histopathological characteristics.[33]

Food uses of fenugreek: Fenugreek has been used in the preparation of many food products. The fenugreek hydrocolloid, specifically fenugreek gum (soluble fibre), has the capability to emulsify, thicken, stabilize, gel and encapsulate substances. Consequently, dietary fiber, particularly soluble fiber, had made its way into dairy products, cereal bars and nutritional drinks.[7] *Uppuma* (kedgeree), laddu (sweet balls) and dhokla (leavened steamed cake) are some of the nutritious traditional snack foods of India that are prepared using a combination of millets, fenugreek seeds and legumes.[58] *Uppuma* and *dhokla* were liked moderately, while laddu was liked slightly. All three food items, *uppuma*, *dhokla* and *laddu*, demonstrated a hypoglycemic effect in terms of glycemic index (GI) and may be crucial in the management of a diabetic person's diet.

Due to its abundance of natural dietary fiber, fenugreek has gained recognition as a useful food ingredient in the contemporary food business. Fenugreek, particularly its soluble fiber, fenugreek gum, is a hydrocolloid that can thicken, emulsify, stabilize, gel and encapsulate various compounds. Dairy products, cereal bars, yoghurts and nutritional drinks all include soluble fiber, which is more crucial than dietary ***fiber (Table 3).***[2,8] Soluble fiber or total dietary fiber powder can be used with fruit juices, spices and other spice mixtures. Along with other necessary vitamins and nutrients, it can be utilized directly to make tablets or capsules. Milkshakes, sauces, soups, candies and

other desserts can also contain it. It has been used to fortify bakery flour for use in the production of corn chips that are fried and baked, as well as cake mix, pizza, muffins, bread, flatbread and noodles. Bakery products including bread, pizza, cakes and muffins are made with flour that has been fortified with 8-10% soluble dietary fiber. Only 8-15% less oil is absorbed when fiber-fortified flour is used to manufacture oil-fried snacks, which represents a considerable reduction in fat intake (Table 3).[59]

Table 3 Food and non-food applications of fenugreek

Application/Uses	Plant part
Bread	Seeds
Functional food	Galactomannan, extract and fibre
Flavouring agents	Seeds, leaves (curries, pickles, condiments)
Alcoholic beverages	Seeds
Stabilizer, Adhesive and Emulsifying agent	Seeds
Cosmetics	Seeds, leaves
Insect repellant	Seeds oil
Fumigant	Leaves

By incorporating fenugreek seeds, Ravindran and Gamlath[60] prepared a useful extruded rice and chickpea snack with good physical and sensory qualities. A 7:3 chickpea and rice mixture with additions of 5, 10, 15, and 20% of deodorized fenugreek powder was used in studies at optimum processing conditions. In order to find out how the prepared products were suitable for use as snack foods, physical (crunchiness, expansion and colour) and sensory (colour, flavour, texture as well as overall acceptability) characteristics were recorded. The products made with 5- 15% of fenugreek powder had acceptable colour, flavour, texture as well as overall quality. However, there were noticeable differences in the expansion, crunchiness and colour values of the product made with 20% deodorized fenugreek powder. They also concluded that fenugreek, in the form of deodorizer powder, could be added up to 15.0% to a chickpea and rice mixture to prepare snack foods with acceptable physical and sensory qualities.

Hegazy and Ibrahim[61] investigated the results of replacing varying percentages of wheat flour (5, 10, 15 and 20%) with soaked or germinated fenugreek seed flours. The findings showed that compared to other blend biscuits, biscuits made using wheat flour and supplemented with (5%) and (10%) of germinated fenugreek seed flours had higher acceptance scores for all sensory characteristics. In comparison to other samples, the sensory panelist found the biscuits containing (15%) and (20%) fenugreek seed flours to be significantly different and unacceptably sweet. According to the results of the chemical analysis, adding more fenugreek seed flours to biscuit formula increased the amount of protein, fat, fiber, ash and essential amino acids. The highest protein efficiency ratio (1.60%), net protein ratio (2.31%) and net protein utilization (60%) were found in the biscuits containing 10% germinated fenugreek seed flours.

In a study, a novel extruded snack with milk solids, fenugreek and a blend of maize: chickpeas (80:20) was developed. The prepared final product was acceptable even after three months.[62] Another study was conducted to develop Tortilla chips adding cowpea and fenugreek, with a 45-day shelf life at 25ºC and it was reported that tortilla chips containing 10% cowpea and 1% fenugreek content, could be made with a good overall acceptability (score value of 7.40) and having higher protein and fiber content i.e. 18.93 and 18.08%, respectively whereas lower fat content (10.25%) was recorded than the control.[63]

Lalit[64] used barley and fenugreek seeds that had been germinated to prepare four products: bread, cake, sweet biscuits and salty biscuits. The germinated fenugreek seed powder was added in different levels i.e. 5.0, 7.5, 2.0 and 1.0% in the products i.e. bread, cake, sweet biscuits and salty biscuits, respectively. In value-added bakery goods including bread, cake, sweet biscuits and salty biscuits, it was advised to combine wheat flour with barley flour (20–25%) and germinated fenugreek seed powder (1–7.5%). Similarly, in another study biscuits were made using mixtures that had various amounts (0, 5, 10, 15 and 20%) of germinated fenugreek seed flour. The biscuits width, thickness, spread ratio and sensory qualities were then assessed. According to the sensory data, only 10% fenugreek seed flour was used to make biscuits of acceptable quality. The organoleptic characteristics of these biscuits were safely preserved by packing in polypropylene bags for up to one month.[7] Also, a study was conducted to develop sugar free biscuits using fenugreek seed powder and stevia as a natural sweetener. SMP (1.7727%), butter (37.8788%), stevia (4.3485%) and fenugreek seed powder (0.5%) were used in the development of sugar free biscuit. The sensory response values recorded for the product were fracturability (41.5894 mm), hardness (0.9788 kg/cm^2), overall acceptability (8.6465), flavour (8.4197) and excellent desirability (0.8951).[65]

Use of fenugreek in milk and milk products: The effects of adding germinated fenugreek blended in permeate to ice milk were investigated. Germinated fenugreek blended in permeate was added to ice milk mix in various amounts (0, 2, 4 and 6%) and the effects on the physical as well as chemical properties were studied. According to the study, elevating the germinated fenugreek blended in permeate ratio in ice milk caused a revolutionary upward push in viscosity and overrun while regularly decreasing the values of precise gravity, pH, melting resistance and freezing point. Ice milk with germinated fenugreek included in permeate dietary supplements at 2 and 4% received favourable sensory rankings. It was determined that germinated fenugreek blended in permeate might be a rich source of nutrients and minerals while used to make ice milk.[66] In another study, black cumin seeds, garlic and fenugreek, which are traditional Indian spices, were added to fermented milk. It was concluded that addition of the traditional spices and fermentation both significantly reduced the number of pathogenic organisms.[67]

Similarly, buttermilk fortified with fiber was prepared using fenugreek powder. The buttermilk samples were made with constant sugar level (5%) and varying level of fenugreek powder (0, 0.15, 0.30, 0.50, 0.70, 0.90, 1 and 1.5%). The higher-quality fiber-fortified buttermilk could be made by mixing 5% sugar and 0.5% fenugreek powder. At a refrigerated temperature of 5±2ºC, the prepared fiber-fortified buttermilk remained in good condition for 48 hours.[68]

Functional buffalo milk yoghurt was made by Dhawi et al.[69] by adding 0.1 and 0.2% of fenugreek seed flour and Moringa oleifera seed flour. Fortification's effects on physico-chemical, total phenolic content, antioxidant activity, yoghurt starter viability and sensory acceptability of yoghurts during cold storage were assessed. When compared to control yoghurt, yoghurt that had been treated with fenugreek seed flour and moringa flour showed considerably increased antibacterial activity against all the pathogenic microorganisms used in the study.

Conclusion

Fenugreek is a nutritionally rich leguminous plant with wide-ranging medicinal, therapeutic and functional food applications. Its seeds are an excellent source of dietary fiber, proteins, essential fatty

acids, minerals, vitamins and bioactive compounds such as flavonoids, saponins, alkaloids and polyphenols, which collectively contribute to its antioxidant, antidiabetic, antimicrobial and anti-inflammatory properties. Extensive research demonstrates fenugreek's effectiveness in regulating blood glucose levels, improving insulin sensitivity, reducing lipid profiles and providing protection against oxidative stress and various chronic diseases. Additionally, fenugreek's antioxidant and antimicrobial activities further support its use in preventing cellular damage and inhibiting pathogenic microorganisms. Toxicological studies confirm that fenugreek is generally recognized as safe, reinforcing its suitability for regular dietary use. Beyond its medicinal value, fenugreek has gained significant importance in the food industry as a functional ingredient due to its emulsifying, stabilizing and thickening properties. Its successful incorporation into bakery products, snacks, dairy products and traditional foods enhances nutritional quality without compromising sensory acceptability. Overall, fenugreek stands out as a valuable natural ingredient with promising potential in functional foods, nutraceuticals and therapeutic applications.

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Conflicts of interest

No potential conflict of interest was reported by the author.

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