

POTENTIAL OF FENUGREEK AS A NUTRACEUTICAL AND FUNCTIONAL FOOD INGREDIENT

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Abstract

There is a great demand for nutraceuticals and healthy foods in today's World. Fenugreek is one of the oldest medicinal plants and is considered to have a good nutraceutical value. It belongs to the category of herbal drugs with minimal or no side effects. Fenugreek is antioxidant, anti-microbial, hypocholesterolemic, anti-carcinogenic, anti-diabetic, immunostimulatory, and a galactagogue. These nutraceutical properties of fenugreek are due to the bioactive components present in it such as diosgenin, galactomannan, etc. Fenugreek can be incorporated into different food products as a functional ingredient to enhance their nutritional value but this may impact the physical, chemical, and organoleptic properties of foods. The present paper reviews the bioactive components and nutraceutical properties of fenugreek with its impact on the properties of foods after being incorporated as a functional ingredient.

Keywords: Nutraceuticals, Fenugreek, Bioactive components, Functional ingredient, Antioxidant, Anti-Microbial, Hypocholesterolemic, Anti-Carcinogenic, Anti-Diabetic, Immunostimulatory, Galactagogue

Introduction

Food is a source of energy, carbohydrates, proteins, vitamins, fat, minerals, fibers, and antioxidants for the human body. The body utilizes these nutrients for its wellness, maintenance, and growth. Nutraceutical is a category of products that lie in between food and pharmaceutical. They are less than pharmaceuticals but more than food. There is no internationally accepted definition for nutraceuticals therefore the opinion about them varies from country to country. After studying different definitions of it we can conclude that nutraceutical is a food or a part of food or a bioactive molecule that is extracted from the actual food matrix that provides medicinal or health benefits.

Products that are included under this term are isolated nutrients, processed foods, genetically engineered designer foods, and herbal products that are used to prevent or treat diseases (Prakash and Boekel, 2010; Dudeja and Gupta, 2017; Télessy, 2019). Food Safety and Standard Authority of India describes nutraceutical as an extract that is isolated and purified from a food or a non-food source that provides physiological health benefits and maintains health and is available in the form of capsules, granules, powder, tablet, etc. (The Gazette Of India: Extraordinary Part 3-Section 4). Nutraceuticals can be isolated, characterized, extracted, and purified from micro-organisms,

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plants, and animals. This also reduces the cost of production. With the advancement in food biochemistry, food technology, and nutritional genomics foods with health benefits are continuously being manufactured or obtained naturally (Jain and Pundir 2013). Candra *et al.* 2019 classified nutraceuticals based on availability as traditional and non-traditional. Traditional nutraceuticals include nutrients (vitamins, amino acids, and fatty acids), herbals, phytochemicals, probiotics, and nutraceutical enzymes. Non-traditional nutraceuticals include foods enriched with supplements such as fortified products for example milk enriched with cholecalciferol. Garima *et al.* (2016) classified nutraceuticals obtained from natural sources into different categories as shown in Figure 1. Nutraceuticals can also be defined as dietary components that are naturally present in foods and have medicinal value. Due to the stressful lifestyle cases of obesity, cardiovascular disorders, osteoporosis, arthritis, etc are increasing rapidly among the population, and in this situation, nutraceuticals can be used as a tool in the prevention of such disorders (Tyagi, 2021).

Fenugreek (*Trigonella foenum graecum*) is of good nutraceutical value and belongs to the category of herbal drugs mainly due to its intrinsic dietary fiber content which contributes to its hypocholesterolemic and antidiabetic property. Fenugreek is an annual plant that belongs to the Leguminosae family. It is widely used as a spice in human food. Figures 3, 4 and 5 show the seeds, fresh leaves, and dried leaves of fenugreek. Green leaves and seeds of this plant are widely used in medicines and foods. They enhance the flavor and color of food as well as modifies its texture. The seeds of this plant are hypocholesterolemic, gastric stimulant, anti-diabetic, anti-bacterial, and anti-cancerous (Shrinivasan, 2006). The nutraceutical properties of this plant are mentioned in Figure 2. Fenugreek aids in digestion, and its seed provides texture to food due to its high dietary fiber content. The high fiber, protein, and gum content make it a suitable food stabilizer, adhesive, and emulsifying agent (Meghwal and Goswami, 2012). *Trigonella* is a Latin word that means 'little triangles' this name is given to it due to its triangular flowers (Flammang

et al., 2004). The areas in which it is commercially grown are India, Pakistan, Iran, Egypt, Nepal, Argentina, France, Afghanistan, Turkey, Spain, Morocco, the Middle East, and North Africa (Ghosh, 2020). There is enough literature on the therapeutic properties of fenugreek and its bioactive components but very few papers highlight its incorporation as a functional food ingredient. These functional foods if incorporated into the daily diets of the population may enhance their health. The term functional implies to those foods that have health benefits and reduce the risk of diseases.

Taxonomic classification:

Kingdom: Plantae

Phylum: Spermatophyta

Class: Dicotyledonae

Order: Fabales

Family: Leguminosae

Genus: *Trigonella*

Species: *T. foenum graecum*

Historical perspective

Fenugreek is one of the oldest medicinal plants known to have originated in central Asia around 4000 BC. Ebers Papyrus, one of the oldest medicinal documents of 1500BC Egypt outlines the descriptions and benefits of fenugreek as a medicinal plant. Ayurvedic texts, Greek and Latin pharmacopeia all describe the medicinal importance of this plant. The aphrodisiac power of this herb is appreciated in Ayurvedic texts. It is used to cure respiratory and digestive problems by modern

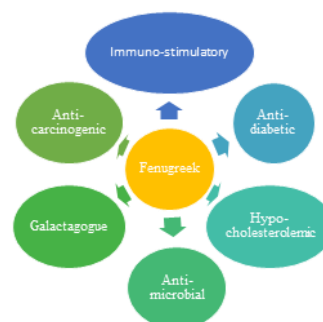


Figure 2. Nutraceutical properties of fenugreek.

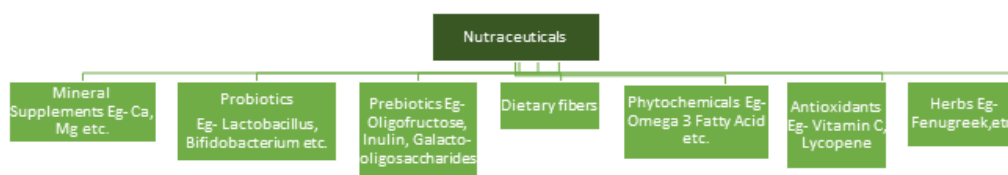


Figure 1. Classification of nutraceuticals.

Ayurvedic doctors. In ancient times, in the middle east, it was used to increase milk flow in mothers suffering from hypogalactia and to ease childbirth. Modern women of Egypt use it to relieve menstrual cramps and make hilba tea of it to relieve abdominal discomfort. The Chinese name of fenugreek is 'hu lu ba' and it is used to treat abdominal pain. It has been used for years to treat the symptoms of colds, influenza, pneumonia, sore throat, and constipation (Ghosh, 2020).



Figure 3. Seeds of fenugreek.



Figure 4. Fresh leaves of fenugreek.



Figure 5. Dried leaves of fenugreek.

Bioactive components of fenugreek

Bioactive components are naturally present in plants and they are also called phytochemicals. They have been classified as primary and secondary constituents. Primary constituents include amino

acids, proteins, common sugars, etc and secondary constituents include plant chemicals such as polyphenols, alkaloids, carotenoids, phytosterols, terpenoids, and saponins. They are known to promote human health (Saxena *et al.*, 2013). Fenugreek is bitter due to the alkaloids and oil components present in it (Altuntas *et al.*, 2005). Components of medicinal importance that are found in the seeds and leaves of this plant are galactomannan, diosgenin, and isoleucine. Diosgenin and yamogenin are two major steroidal sapinogens found in fenugreek. Gentanin, carpaine choline, and trigonelline are three major alkaloids found in fenugreek. Diosgenin is used in the preparation of commercial steroids (Mehbub *et al.*, 2018). Singh *et al.*, 2020 reported other bioactive components such as pinitol, isovitexin, isoorientin, vitexin, sarsasapogenin, 4-hydroxy isoleucine, and orientin that have been identified from fenugreek by the HPLC method. Fiber is also a major component of fenugreek seeds (Salehi, 2008). Qualitative phytochemical analysis of ethanol extracts of fenugreek seeds can be done by the following tests-Mayer and Wager test for alkaloids, lead acetate tests for flavonoids, Liebermann-Burchard and H₂SO₄ test for steroids, FeCl₃ test for tannins, Borntrager test for Anthraquinones and Keller-Kiliani test for terpenoids. Khamees *et al.* (2020) revealed the presence of tannins, anthraquinones, alkaloids, steroids, and terpenoids in the ethanolic extracts of fenugreek seeds. Mahmood and Yahya (2019) reported the presence of alkaloids, flavonoids, carbohydrates, steroids, terpenes, saponins, tannins, glycosides, free amino acids, crude proteins, and phenolic compounds in the fenugreek seed extract. This study also showed that the concentration of phytochemical compounds is different for different solvents (Table 1). From the results obtained in this study, it was found that the aqueous extract of fenugreek seed powder is rich in alkaloids, saponins, amino acids, terpenoids, tannins, phenolic compounds, carbohydrates, flavonoids, and proteins. They also contain small amounts of steroids and glycosides but oil was found to be absent. Ethanolic extract of fenugreek seed powder was found rich in flavonoids, carbohydrates, steroids, glycosides, amino acids, terpenoids, and fewer amounts of alkaloids, phenolic compounds, saponins, proteins, and present in very high amounts in fenugreek. Preliminary and qualitative analysis of phytochemicals in leaves, seeds, and stem extract of fenugreek was performed by Rehman *et al.* 2012. The results obtained from this study are discussed in Table 2. Bio-active lipid constituents found in fenugreek are triacylglycerols, phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol,

linoleic acid, linolenic acid, oleic, and palmitic acid. The presence of oleamide a member of N-acylethanolamine and N-acyl phosphatidylethanolamines has also been reported in fenugreek by Chatterjee *et al.* (2010). Fenugreek is also a good source of carotenoids iron, vitamin A, vitamin B, and vitamin C. Important

phytochemicals of fenugreek are summarized in Table 3.

Nutraceutical properties of fenugreek

Nutraceutical properties of fenugreek and the phytochemicals associated with them have been summarized in Table 4.

Table 1. Comparative study of phytochemicals present in aqueous and ethanolic extracts of fenugreek seed powder.

Aqueous Extract of Fenugreek Seed Powder	Ethanolic Extract of Fenugreek Seed Powder
Present in high amounts: proteins, saponins, amino acids, terpenoids, tannins, phenolic compounds, carbohydrates, flavonoids, alkaloids	flavonoids, carbohydrates, steroids, glycosides, amino acids, terpenoids
Present in small amounts: Steroids Glycosides	Present in small amounts: alkaloids, phenolic compounds, saponins, proteins, and tannins

Table 2. Phytochemicals present in leaf, stem, and seeds of fenugreek.

Leaf	Stem	Seeds
Phenols	Sterols	Phenols
Sterols	Alkaloids	Sterols
Flavonoids	Glycosides	Flavonoids
Alkaloids	Saponins	Alkaloids
Saponins	Quinones	Glycosides
Quinones		Saponins
		Quinones

Table 3. Important phytochemicals of fenugreek.

Carbohydrates	Galactomannan
Steroidal Sapinogen	Diosgenin, Yamogenin, Sarasapogenin
Amino acids	Isoleucine 4-Hydroxyisoleucine
Alkaloids	Gentanine, Carpaine choline, trigonelline
Flavones	Isovitexin, Isoorientin, Orientin, Vitexin
Cyclitol	Pinitol
Polyphenols	Tannins
Quinones	Antraquinones, terpenoids
Lipids	triacylglycerols, phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol, linoleic acid, linolenic acid, oleic and palmitic acid
N-acylethanolamine oleamide	oleamide
Others	Vitamins, minerals etc.
Mehbub <i>et al.</i> 2018; Singh, <i>et al.</i> , 2020; Chatterjee <i>et al.</i> , 2010	

Table 4. Nutraceutical properties of fenugreek with the related bioactive components.

Nutraceutical Property	Bioactive component	References
Antioxidant	Polyphenols and flavonoids -Vitexin, Isovitecin and Kaempferol rhamnoside	Dixit, <i>et al.</i> 2005 Khole, <i>et al.</i> 2014
Antimicrobial	Flavonoids, Tannins	Chalghoumi, <i>et al.</i> 2016
Hypocholesterolemic	Saponins and fibers	Goyal, <i>et al.</i> 2016
Antidiabetic	Galactomannan, 4-hydroxyisoleucine	Anwar, <i>et al.</i> 2011
Anticarcinogenic	Diosgenin, yamogenin, trigoneoside, protodioscin, naringenin, quercetin, and squalene	Raju, <i>et al.</i> 2004 Varjas, <i>et al.</i> 2011; Khalil, <i>et al.</i> 2015
Immunostimulatory	Saponins, flavonoids, and fibers	Bin-Hafeez, <i>et al.</i> 2003
Galactagogue	Phytoestrogen, Diosgenin	Turkylmaz, <i>et al.</i> 2011

Antioxidant

Many foods are loaded with antioxidants that are known to prevent or delay cell damage. Food is oxidized in cells this oxidative metabolism is essential for the survival of cells but this process generates reactive oxygen species and free radicals. These free radicals if formed in excess may damage cells by oxidation of lipids, cellular proteins, DNA, and enzymes. This damage can be prevented by the consumption of traditional herbal medicines that are rich in antioxidants such as fenugreek. Consumption of foods rich in antioxidants may prevent diseases such as cancer and coronary heart disease (Antolovich *et al.*, 2002; Yadav *et al.*, 2016). Germinated fenugreek seeds are high in antioxidant activity due to the high content of polyphenols and flavonoids present in them (Dixit, *et al.*, 2005). Antioxidants that are isolated from fenugreek seed extract are vitexin, isovitexin, and kaempferol rhamnoside (Khole *et al.*, 2014). Ethanol is the best solvent to extract phenols and flavonoids from fenugreek leaves. A high level of lipid peroxidation inhibitory activity with DPPH scavenging activity is

exhibited by the ethanolic extracts of fenugreek (Premnath *et al.*, 2011). The activities of antioxidant enzymes and vitamin C are increased on the consumption of fenugreek mucilage (Sindhu *et al.*, 2012). Antioxidant activity can be measured by measuring the total phenolic content (TPC) by the Folin-Ciocalteu method, flavonoid content, chelating activity, 1, 1-diphenyl 1-2-picrylhydrazyl (DPPH) free radical scavenging activity, and reducing power. Fenugreek seeds powder suspension enhances the antioxidant defense mechanisms of the body (Marzouk *et al.*, 2013). The antioxidant potential of seeds can be improved by the application of CO₂ to the seeds (Hozzein *et al.*, 2019). Fenugreek shoots are a better source of antioxidant compounds as compared to fenugreek seeds (Baba and Bhat, 2018).

Antimicrobial

Bacteria are becoming antibiotic-resistant for the last three decades, therefore, to combat this problem research is being conducted throughout the world to extract antimicrobial compounds from different plant sources. Walli *et al.* (2015) investigated the antimicrobial activity of fenugreek seeds in vitro against both gram-positive and gram-negative bacteria by using methanol and aqueous extractions in boiling, cold and hot water. Agar disc diffusion and agar-well diffusion methods were used for the evaluation of the antimicrobial activities of the extracts. The results obtained in this test showed that boiling water extract of fenugreek seeds has anti-microbial activity against *Staphylococcus aureus* but not against other bacterial species. Cold aqueous extract and methanol extracts showed negative results for all the bacterial species tested. Other *Staphylococcus* species (*St. epidermis*, *St. aureus*, and *St. saprophyticus*) were also found sensitive to the boiling water extract of fenugreek. Sharma *et al.* (2017) reported methanol extract of fenugreek leaves has the highest anti-microbial activity against *Staphylococcus* and *E.coli*. It was concluded from this study that the order of antibacterial activities of solvent extract of Fenugreek is Methanol>Acetone>Aqueous. Al-Timimi (2019) reported that the seed extract of fenugreek exhibits the highest antimicrobial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Baba and Bhat (2018) reported, methanolic extract of fenugreek shoots also shows antimicrobial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Chalghoumi and Hedi (2016) reported that flavonoids and tannins are two major phytochemicals that are known to have antimicrobial activity in aqueous and methanolic extracts. Phytochemicals with

antimicrobial potential that have been isolated from fenugreek seeds are mentioned in Table 5 (Priya *et al.*, 2011).

Table 5. Phytochemicals with antimicrobial activity isolated from fenugreek.

Phytochemical with antimicrobial activity	Molecular formula
Aziridine, 1,2,3- trimethyl-, trans-	C ₅ H ₁₁ N
2-Propen-1-amine, N-ethyl-	C ₅ H ₁₁ N
1- Azabicyclo[2.2.2]octane, 4-methyl	C ₈ H ₁₅ N
Dibutyl phthalate	C ₁₆ H ₂₂ O ₄
Hexane, 3-bromo	C ₆ H ₁₃ Br
Piperidine, 1,1'- methylenebis-	C ₁₁ H ₂₂ N ₂
1-Octanol, 2-nitro-	C ₈ H ₁₇ NO ₃
Pentanal, 2-methyl-	C ₆ H ₁₂ O
Didodecyl phthalate	C ₃₂ H ₅₄ O ₄
Squalene	C ₃₀ H ₅₀

Hypo-cholesterolemic activity

It was reported by Sowmya *et al.* (2020) that the consumption of germinated fenugreek seed powder in a significant amount mixed into any dish regularly for thirty days may result in a significant reduction in the total LDL and cholesterol levels. Belguith-Hadriche (2013) reported that only ethyl acetate extract of fenugreek seeds reduced cholesterol, low-density lipoprotein cholesterol, and triglycerides in cholesterol-fed rats. A combination of fenugreek, cumin, and ajowan seed extracts shows a high hypocholesterolemic activity as compared to individual extracts (Gurunath, 2019). Goyal *et al.* (2016) reported saponins and fibers are mainly responsible for the hypocholesterolemic activity of fenugreek extracts. Fenugreek consumption increases cholesterol excretion because the reaction between bile salts and saponins leads to the formation of micelles that are too large to get absorbed by the digestive tract and the seeds being high in fiber content reduces the rate of hepatic cholesterol synthesis. Both of these mechanisms lead to cholesterol-lowering in the blood serum (Narender *et al.*, 2005).

Antidiabetic

Herbal drugs are widely used in the treatment of diabetes. These plants contain alkaloids, glycosides, terpenes, flavonoids, etc which have an anti-diabetic effect as these components restore the functions of pancreatic tissue that leads to an increase in the insulin output. These substances may also hamper the absorption of glucose. Therefore, consumption of these herbal drugs protects beta-cells and prevents fluctuations in glucose levels (Loew and Kaszkin, 2002; Jia *et al.*, 2003; Elder, 2004). The role of fenugreek alkaloid extract was evaluated on streptozotocin-induced diabetic rats

and it was observed from this study that administration of fenugreek alkaloid maintains blood glucose to normoglycemia during diabetes. In addition to this, it reduces the impact of diabetes on the cells of the liver and kidney (El-Soud *et al.*, 2007). Galactomannan has the potential to lower blood glucose levels and it is the main component of fenugreek seeds that is responsible for their anti-diabetic property. Alcohol extract of fenugreek seeds is found to restore the activities of the key enzymes in lipid and carbohydrate metabolism. Therefore, alcoholic extract of fenugreek can be used in the management of diabetes mellitus (Anwar *et al.*, 2011). Another component of fenugreek is 4-hydroxy isoleucine which increases secretion of pancreatic insulin and inhibits glucosidase activity (Lu *et al.*, 2008).

Anti-carcinogenic

The fenugreek seed extract is cytotoxic to cancer cells. Shabbeers *et al.* (2009) reported that fenugreek extract at the concentration of 10-15ug/ml for 72 h is inhibitory to prostate, pancreatic, and breast cancer cell lines. Even at a higher concentration this extract was inhibitory to cancer cells but was not harmful to normal cells. Abas and Naguib (2019) reported that the process of germination increases the phytochemicals in seeds therefore, germinated seed extract of fenugreek is a more effective anti-cancerous agent than dry seed extract but both the extracts are capable of inducing cell death in human breast cancer cell line (MCF-7 cell line) and pancreatic cancer cell line (AsPC-1). In another study, Al-Timimi (2019) reported that fenugreek seed extract shows inhibition of MCF-7 breast cancer cells at a concentration of 400ug/ml at the incubation period of 72 h but this extract shows no anti-cancerous activity against cancerous liver HCAM cells. Diosgenin, a steroidal saponin present in fenugreek seed extract has the potential to prevent colon cancer as reported by Raju *et al.* (2004) that diosgenin induces apoptosis and inhibits cell growth in HT-29 human colon cancer cells. Yamogenin, trigoneoside, protodioscin, naringenin, quercetin, and squalene are other bioactive compounds isolated from fenugreek that are known to possess anti-carcinogenic activity as reported by Varjas *et al.* (2011); Khalil *et al.* (2015).

Immunostimulatory

Fenugreek belongs to the category of herbal drugs which possess immunomodulatory properties that stimulates both nonspecific and specific immunity. Therefore, the consumption of fenugreek strengthens the immune system. Herbal tea is made with a combination of fenugreek, honey and lemon is a traditional remedy to treat fever. It is widely

used in Ayurvedic and Unani drugs due to its immunostimulatory effect. Swiss albino mice were used for the evaluation of the immunomodulatory activity of aqueous extract of fenugreek. Mice were treated with three different doses of fenugreek extract for 10 days and from the results, it was concluded that 100 mg/Kg dose of fenugreek has effective immunostimulatory effects on mice. The extract is responsible for increasing the cell counts of bone marrow as it has a stimulatory effect on hematopoietic stem cells of bone marrow. The bioactive molecules responsible for the immunostimulatory effects of fenugreek are saponins, flavonoids, and fibers (Bin-Hafeez *et al.* 2003). Ethanolic extract of fenugreek was studied by Tripathi *et al.* (2012) for its phagocytic activity, humoral and cell-mediated immune system on mice. The tests that were used to access the immunomodulatory effects were T-cell population test, Delayed type hypersensitivity (DTH), carbon clearance test, and sheep erythrocyte agglutination test. The mice were treated with fenugreek at the dose of 200-400mg/Kg body weight. The results, from this study, showed that phagocytic activity was increased in fenugreek-fed rats as compared to control groups. Anti-inflammatory activity of fenugreek was indicated by a decrease in mean foot paw thickness in DTH. The T-cell formation was also increased in the fenugreek-fed mice.

Galactagogue

Mother's milk is very important for the child's health after birth. Fenugreek is recommended for breastfeeding women with hypogalactia because fenugreek is a galactagogue (Shawahna *et al.*, 2018). Galactagogue is an artificial or natural substance that increases the production of breast milk. Since ancient times fenugreek is consumed as a galactagogue in the middle east. Consumption of fenugreek herbal tea in the early postpartum days is useful in promoting and increasing breast milk production (Sakks *et al.*, 2014). Physiological problems in milk production cannot be treated by the consumption of fenugreek (Sevrin *et al.*, 2019). Diosgenin and phytoestrogen present in fenugreek are known to increase the production of breast milk (Turkyilmaz *et al.*, 2011).

Impact on the properties of foods after incorporation of fenugreek as a functional ingredient

Dairy products

Functional yogurt can be produced by the incorporation of traditional herbs or bioactive components present in them. Functional buffalo yogurt was produced by Dhawi *et al.* (2020) by the

addition of 0.2% and 0.1% of fenugreek seed powder, and the effects of fortification were evaluated on pH and titratable acidity, the viability of starter culture, total phenolic content, antioxidant activity, and its sensory acceptability. The results obtained from this study showed that the fortified yogurt increased in titratable acidity and decreased in pH during the storage period of 14 days. The addition of fenugreek seed powder to yogurt decreased syneresis because it increased the soluble fiber content and total solids in the fortified yogurt preventing the drainage of whey. Fenugreek seed powder is high in polyphenols. Therefore, its incorporation in yogurt increased the total phenolic content and antioxidant activity of yogurt which decreased during the storage period. Functional yogurt was high in nutritional value due to the high mineral content of fenugreek seeds. The mineral content of functional yogurt increased on storage. The viability of *Streptococcus* and *Lactobacillus* was increased in fortified yogurt. The sensory acceptability of fortified yogurt with 0.1% fenugreek seed powder was more than the fortified yogurt with 0.2% fenugreek seed powder and it was concluded from this study that fenugreek seed powder can be used to enhance the nutritional composition of yogurt without much affecting its sensory attributes.

Cheese made from goat's milk is not preferred by many people due to its distinct goaty smell. The organoleptic properties and chemical composition of cheese made by goat's milk can be improved by the addition of herbs such as fenugreek. In the study conducted by Hamid and Nafessa (2012) fenugreek seed powder at a concentration of 0.02% was added before drainage to the curd during the production of cheese by goat's milk and cheese without any additive was used as a control. The produced cheese was subjected to sensory evaluation and it was concluded from the results that spices can be used to improve the color and odor of goat's milk cheese. The chemical composition of the produced cheese samples was studied and the results showed that the fat, proteins, and ash content of the cheese were affected by the addition of fenugreek. The total solids and acidity of the produced functional cheese were found similar to the control samples. Fenugreek has therapeutic properties and it is also rich in vitamin A, C, B6, iron, and magnesium. Therefore, herbal paneer prepared by incorporating fenugreek at the stage of curd before pressing may be nutritionally rich and with improved shelf life (Trehan *et al.*, 2019).

Bakery products

Bakery products are high in glycemic index. The incorporation of fenugreek seed flour in such

products may enhance the nutritional, organoleptic, and physiological properties of these products. Flatbread and buns were prepared by Robert *et al.* (2015) by the addition of 10% fenugreek seed powder. The addition of fenugreek seed powder to flatbreads and buns reduced their glycemic index. Likert scale results for the prepared functional buns revealed that 80% of individuals were either neutral or liked the functional buns and 20% of individuals disliked them. Functional flatbreads were liked by all according to the Likert scale results.

Cookies can be ideal for the incorporation of fenugreek so that the health-promoting compounds possessed by fenugreek can be delivered to the consumers. The incorporation of fenugreek seed powder with wheat flour in the production of cookies is not much explored. In the research conducted by Sonu *et al.* (2015) cookies were developed by the incorporation of fenugreek seed extract and fenugreek seed powder in varying proportions, and their impact on the physical and sensory characteristics of the cookies was studied. The results obtained from this study showed that the addition of fenugreek seed powder to cookies decreased the width of the cookies due to the increased viscosity of the cookie dough. The spread ratio of the cookies was reduced with the addition of fenugreek seed powder. The hardness of the cookies increased with the addition of fenugreek seed powder. Sensory evaluation of the cookies revealed that simple wheat flour cookies that were used as a control were highly acceptable and cookies containing 1, 2% fenugreek seed powder were also acceptable but the values of acceptability decreased strongly for cookies with 3, 4% fenugreek seed powder. Flatbread is very popular throughout the world. Few examples of flatbread are tortilla, chapati, pancake, etc. Functional ingredients are being incorporated in flatbreads throughout the world to increase their nutritional value and shelf life. Fenugreek leaves are incorporated in the Indian flatbread (parotta) to enhance its flavor but the addition of fenugreek seed powder to Indian parotta is not much explored. In the research conducted by Indrani *et al.* (2010) the influence of fenugreek seed powder at the concentration of 0, 2.5, 5, 7.5% on the rheological characteristics of wheat flour dough for parotta and its quality were studied. Water absorption, peak viscosity, spread ratio increased with increasing fenugreek seed powder in the dough. Extensibility and shear force decreased with the increasing fenugreek seed powder in the dough. According to the sensory evaluation of the produced functional parottas. Parottas with 5% fenugreek seed powder were found most acceptable. In the research conducted by Afzal *et al.* (2016) fenugreek seed powder was incorporated in bread at the

concentration of 5%, 10%, and 15%, and its nutraceutical and antioxidant potential were evaluated. Flavonoid content and antioxidant potential of the flour and bread supplemented with fenugreek increased with the increasing concentration of fenugreek seed powder. In the sensory evaluation of the functional bread, bread supplemented with 10% fenugreek seed powder was found most acceptable.

In the research conducted by Shrivastava *et al.* (2012) fenugreek seed husk was incorporated in muffin at the levels of 5, 10, 15%, and its effect on their quality and sensory characteristics were studied. Chemical analysis of wheat flour and fenugreek seed husk blends revealed that with the increasing levels of fenugreek seed husk, moisture and gluten content decreased and fat, ash, protein values increased. The yellowness of the muffins increased with the increasing level of fenugreek seed husk due to carotene present in fenugreek seeds. Batter density and viscosity increased with the increasing fenugreek seed husk in the batter. The volume of the muffin increased with the increasing fenugreek seed husk and they became tender and crumbly in texture. In the sensory evaluation, muffins with 10% fenugreek seed husk were found most acceptable and their quality improved with the addition of emulsifiers. Therefore, fenugreek seed husk is an ideal ingredient for the manufacture of high fiber muffins.

Extruded products

Nutritional properties of extruded products such as noodles can be enhanced by the addition of fenugreek. It will also help in lowering the glycemic index of these foods. In the study conducted by Najeeb *et al.*, (2018) functional noodles were prepared by the addition of fenugreek leaves puree at the concentration of 0%, 10%, 20%, 30%, 40%, and 50%. From the sensory evaluation of these functional noodles, it was concluded that noodles with a 30% concentration of fenugreek leaves puree were found acceptable. It was found good in color, flavor, taste, and texture. The results from this study revealed that as the concentration of fenugreek leaf puree in noodles increased there was an increase in moisture, decrease in fat, decrease in protein, decrease in carbohydrates, increase in fiber and ash content of the noodles. The content of minerals such as calcium, phosphorus, potassium, copper, ferrous, zinc, and magnesium increased with the concentration of fenugreek leaves puree in the noodles.

In the study conducted by Wani and Kumar (2015) the effect of the addition of fenugreek seed powder and fenugreek leaves powder on the

physical and functional properties of extruded products was studied. The addition of fenugreek leaf powder to extruded products decreased hardness, water solubility index, and lateral expansion. It was concluded from this study that the blend of 21.72% of oat flour, 8.62% dried green pea flour, 1.78% of fenugreek seed powder, and 0.66% of fenugreek leave powder and composite flour (rice+corn flour) for the formation of the extruded product was highly preferred. Therefore, the potential of fenugreek as a functional ingredient to enhance the nutritional value of products such as pasta needs to be explored. In the research conducted by Jyotsana *et al.*, 2010 the effect of fenugreek seed powder on the textural and microstructure characteristics of vermicelli was studied. Functional vermicelli was prepared by substituting semolina with fenugreek seed powder at the levels of 2.5, 5.0, 7.5, and 10%. The results obtained from this study showed that gelatinization temperature decreased and peak viscosity increased with the increase in fenugreek content of the vermicelli samples. Vermicelli samples with added fenugreek were dull in color as compared to control samples. The cooked weight, sheer value, and cutting stress of the vermicelli samples increased with the increase in the level of fenugreek supplementation because the firmness of the samples increased. In the sensory evaluation, vermicelli samples with 7.5% fenugreek were rated the best according to the taste and firmness of the samples.

In the research conducted by Shirani and Ganesharanee (2009) chickpea and rice-based extruded products were prepared by the addition of fenugreek flour and debittered fenugreek polysaccharide and their impact on the physical and sensory quality of the products was studied. Products prepared by only chickpea and rice blend in the ratio of 70:30 were chosen as control and this blend was replaced by fenugreek flour at the rate of 2,5 and 10% or fenugreek polysaccharide at the rate of 5, 10, 15, 20%. Extruded products with 5 and 10% fenugreek flour were bitter and not acceptable only products with 2% fenugreek flour were acceptable. Extruded products formed by the addition of debittered fenugreek polysaccharides were reduced in radial expansion, increased in longitudinal expansion, increased in water absorption index, and decreased insolubility index. The addition of debittered fenugreek polysaccharide to chickpea-based extruded products was found acceptable up to 15% and it was concluded from this study that snacks with low glycemic index can be produced by the blend of chickpea and rice flour with debittered fenugreek polysaccharide up to 15%.

Juices

Fenugreek mucilage is derived from the seed of endosperm. It is composed of mannose and galactose and is also known to increase the viscosity of aqueous solutions. In a study conducted by Aruna *et al.* (2017), mucilage was extracted from fenugreek seeds and added to mosambi juice at the rate of 50mg, 75mg, and 100mg. Samples with no added mucilage were used as control and the properties of all the samples were studied. It was found from the results that the total soluble solids increased in the mosambi juice samples on the addition of fenugreek mucilage and the viscosity of the samples decreased with the increase in the concentration of fenugreek seed mucilage. An increase in the shelf life of the mosambi juice with 100 mg of fenugreek mucilage was observed because it brought a significant decrease in the pH value. Titratable acidity of the samples added with mucilage increased. It was concluded from this study that the use of fenugreek mucilage in the clarification of orange juice is a feasible method and similar to enzymatic treatment.

In the study conducted by Gupta *et al.* (1998) fermented fenugreek leaves juice was prepared by following these steps-cutting, washing, blanching, cooling and grinding fenugreek leaves, mixing vegetable pulp and 2% dextrose solution, inoculating with *Pediococcus pentosaceus*, incubation at 37 degree Celsius, centrifugation, filtration, bottling, sealing and pasteurizing. The prepared fermented fenugreek leaves juice was found high in protein and fat content as compared to the juice prepared by unfermented fenugreek leaves. Vitamin B12 was formed in fermented fenugreek leaves juice with an increase in the pyridoxine and vitamin C content. In the sensory evaluation, the cultured fermented fenugreek leave juice was found highly acceptable and was good in physical appearance, aroma, mouthfeel, and taste. This juice can be incorporated at different levels in fruits and vegetable juices to enhance their nutritional value.

Non-vegetarian products

Rabbit meat is a highly nutritious addition of non-meat ingredients such as fenugreek to it may enhance its quality. In the study conducted by Zaki (2018), quality characteristics of rabbit sausage with added fenugreek seed powder at the level of 5,10, and 15% were evaluated. The results of this study revealed that the pH of the produced functional sausages was higher than the control samples. With the increasing level of fenugreek seed powder in the sausages cooking loss decreased and yellowness increased. The color of the sausages was influenced by the storage period. It was concluded from this study that the addition of fenugreek seed powder to rabbit sausages decreased lipid oxidation.

Therefore, it can be used as a natural antioxidant in such processed products without degrading their sensory and nutritional characteristics.

Processed foods that are made of goat meat for example-nuggets, etc contain undesirable fats. The addition of a functional ingredient such as fenugreek or a combination of functional ingredients to goat meat may decrease its undesirable fat content without affecting its acceptability, taste, and texture. Goat meat is high in protein, iron, potassium, vitamin B, and zero in fiber content. The addition of functional ingredients to it may increase the fiber content and antioxidant potential of the functional meat product (Kausar *et al.*, 2021).

Hen meat is of low quality and is not shelf-stable addition of fenugreek as a functional ingredient in the development of hen meat products may extend its shelf life and improve its quality. In a study conducted by Qureshi *et al.* (2018) functional patties were prepared by the addition of fenugreek seed powder at the rate of 0.5, 1, 1.5, and 2% to hen meat, and patties with no added fenugreek powder were used as control. The produced samples were estimated for their thiobarbituric acid reactive substance (TBARS) value, DPPH assay, cooking yield, pH, proximate composition, microbiological quality, and sensory evaluation. The results obtained in this study showed that cooking yield and pH increased with the increase in the level of fenugreek seed powder in the patties. Moisture, protein, fat, and ash percentage in the functional patties increased with the increasing concentration of fenugreek seed powder. Fenugreek seeds are high in antioxidants therefore the DPPH-RASA increased significantly with increasing fenugreek seed powder in the patties. Sensory attributes like appearance, flavor, texture, juices, mouthcoating and overall acceptability declined but this decrease was not significant in comparison to control up to samples added with 1.5% fenugreek seed powder. Patties with 2% fenugreek seed powder showed a significant decline in sensory attributes. Therefore, fenugreek seed powder can be incorporated up to 1.5% in hen meat-based patties to increase their nutritional value without having much impact on its sensory attributes.

Confectionery

The addition of fenugreek to chocolates may enhance its phenolic content and antioxidant potential but this may negatively affect its sensory quality and consumer acceptance. In the study conducted by Muhammad *et al.* (2021) functional chocolate formulated by the addition of 10% fenugreek seed powder was investigated for consumer acceptance and chocolate without any functional ingredient was used as a control. The

prepared functional chocolate was disliked by the consumers due to its distinct aroma and bitter taste of the fenugreek compounds. The appearance of the produced functional chocolates was similar to the control samples but flavor and taste were strongly affected.

Conclusions

Fenugreek is used since ancient times to treat the symptoms of colds, influenza, constipation, pneumonia, and sore throat. It is considered to have a high nutraceutical value. Phenols and flavonoids present in fenugreek are responsible for their antioxidant property. Fenugreek seed extracts mainly have anti-microbial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Saponins and fibers present in fenugreek are responsible for its hypocholesterolemic activity. Galactomannan and 4-hydroxy isoleucine contribute to the anti-diabetic property of fenugreek. The seed extract of fenugreek if administered at proper doses is cytotoxic to breast and pancreatic cancer cells but has no impact on normal cells. A phytochemical called diosgenin which is known to prevent colon cancer is also present in fenugreek. Women with hypogalactia are recommended to consume fenugreek as a galactagogue because diosgenin and phytoestrogen present in it increase milk production. The benefits from this small herb are numerous and require investigation. Due to changing lifestyle and emerging diseases research is being conducted throughout the world to develop functional foods which have additional health benefits. Fenugreek due to its therapeutic properties can be incorporated into foods as a functional ingredient but its level should be optimized to have no or minimal adverse effects on the properties of the functional product.

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