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Health benefits and improvements of Fenugreek (*Trigonella foenum-graecum* L.) Crop

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ABSTRACT

Remarkable therapeutic and nutritional profile of medical plant fenugreek and its particular chemical composition count valuable as food and medicine. Significant quantity of fiber, phospholipids, glycolipids, oleic, linolenic, and linoleic acids, choline, vitamins A, B1, B2, and C, nicotinic acid, and niacin are all present in fenugreek seeds. In addition to its organoleptic qualities, fenugreek is incredibly nutritious and, when grown for both human food and fodder, has a positive impact on health. The seed of fenugreek has a high content of dietary fiber, which contributes significantly to its capacity to moderate the metabolism of glucose in digestive tracts and subsequently lowers the absorption of glucose in the intestines, so regulating blood sugar levels. The greater amount of soluble fiber in fenugreek makes it more effective at reducing blood sugar levels. When first introduced, its fiber greatly increased satiety and decreased energy intake, suggesting a short-term positive effect on obese people. It can thrive in a wide variety of environments and is only moderately sensitive to salinity and drought. These qualities and the potential for heavy metal remediation make fenugreek a good choice for a variety of cropping systems. Genetic diversity among various accessions may be mapped, and crop improvement and breeding initiatives may be started to enhance the biomass as well as the nutritional and functional components. This is to highlight the importance of fenugreek for both human and animal health in terms of nutrition, biochemistry, functionality, and medicine, as well as its pharmacological presumptions.

Keywords: Fenugreek; nutritional; biochemical; pharmaceutical; Crop improvement; research gap.

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Introduction

Foods that provide significant nutrition, exert health advantages, inhibit disease and/or assist health have become more readily accepted by the industry and can be used as successful marketing tools. This has caused the emergence of functional foods that comprise a wide range of components such as probiotics, prebiotics, vitamins, minerals and dietary fiber (Nematollahiet al., 2016). In this respect, some herbs have been considered for their application as an antioxidant, antimicrobial, health promotion and food development. To create powders and extracts for medicinal use, the plant's seeds, leaves and sometimes the entire plant are employed. One of the first known food and medicinal plants is fenugreek. Fiber, phospholipids, oleic and linoleic acids, choline, vitamins, nicotinic acid, niacin, and amino acids are also abundant (Ahmad et al. 2016). A nutritious diet and medicinal herbs continue to be the cornerstone for maintaining a healthy lifestyle and well-being despite significant advances in medicine and combinatorial drug development, especially in regard to chronic disorders like cancer, cardiovascular diseases (CVDs), and diabetes. Numerous crop plants have beneficial nutritional, practical, medicinal, and nutraceutical qualities.

Fenugreek is grown mainly in China, India, Turkey, Canada, Australia, northern and southern Africa, and southern Europe (Ahmad et al. 2016). It is also, widely grown in Ethiopia and ranks sixth among the highland pulses (Fikreselassie et al., 2012) and also, traditionally small portion of fenugreek is blended into cereals and used for making injera, mainly because of its aromatic compounds and extending the shelf life. Fenugreek was also used in ancient Egypt's incense and to embalm mummies. Because it is

thought to increase breast milk production in postnatal mothers, fenugreek is primarily consumed by nursing mothers in Ethiopia (Forinash et al. 2012). Additionally, historically, a small amount of fenugreek is blended into cereals and used to make injera, primarily because of its aromatic compounds and ability to prolong shelf life. Fenugreek was used as a condiment and lactation stimulant in the Indian subcontinent (Betty, 2008). Fenugreek seeds were allegedly used in ancient Rome to relieve labor pain and deliver babies, while they were also employed in traditional Chinese medicine as a tonic and a therapy for edema and leg weakness (Yoshikawa et al., 2000). Fenugreek seeds have long been utilized as a diabetes treatment in several Asian and African cultures. Fenugreek seeds have long been utilized as a diabetes treatment in several Asian and African cultures. The main findings of human and animal research (Basch et al., 2003), support numerous more traditional uses of fenugreek.

In addition, there are large amounts of fiber, phospholipids, oleic and linoleic acids, choline, vitamins A, B1, B2, C, nicotinic acid, niacin, and amino acids (Ahmad et al., 2016). It can be used to augment cereal grains and has more protein than cereal grains (Yigzaw et al., 2004). Additionally, it can be applied to alter the taste, color, or texture of food. Only a few studies have been done for its genetic upgrades and development of production agronomy, despite its extraordinary nutritional and therapeutic properties. In this review, pharmacological presumptions and the functioning and medicinal relevance of fenugreek have been examined. Additionally, areas for future research are suggested to increase its production and adaptability.

Nutraceutical Constituents of Fenugreek

A distinctive functional food crop is fenugreek (Meghwal and Goswami, 2012). The chemical composition of both the seed and the leaves has made them valuable as food and medicine. They deliver a variety of phytochemicals, which are non-nutritive plant chemicals with protective or disease-preventive properties. These phytochemicals confer the medicinal values as well as impart the well-known spicy flavor. Organoleptic qualities and nutrient contents are two categories that can be used to categorize many aspects of the nutritional value.

Fenugreek seeds are well-liked and well-known for their potently spicy flavor and high fiber content (Najma et al., 2011). Fenugreek leaves that have been dried are used to flavor meat, fish, and vegetable dishes. The primary ingredient behind fenugreek's distinctively sweet scent is sotolon. Small amounts of volatile and fixed oils can be found in fenugreek seeds (Sowmya and Rajyalakshmi, 1999). These compounds include: Olfactometry diacetyl; 1-Octene-3-one; (Z)- 1,5-Octadiene-3-one; 3-isopropyl-2-methoxypyrazine; acetic acid; 3-isobutyl-2-methoxypyrazine; linalool; butanoic acid; isovaleric acid; caproic acid; and eugenol. Gas chromatography has assisted in the 4-dihydro-2(5H)-furanone, 3- amino-4, 5-dimethyl-3. Fenugreek contains the most sotolon (95%) of all of these substances (Blank et al., 1997). This flavor content may be very helpful in encouraging the consumption of meals with good nutrition to maintain good health.

Aside the organoleptic properties, fenugreek is highly nutritious, and could greatly impact health when used as forage crops as well as for human consumption. As it has been widely used as traditional food, functional food and nutraceuticals, it provides natural food fiber and other nutrients required in body. In terms of protein contents, fenugreek has a chemical composition that mimics milk in its ratio between protein and amino acids contents (Acharya et al., 2004). Fenugreek endosperm is rich in protein such as globulin, histidine, albumin and lecithin (Naidu et al., 2011). The fenugreek protein fraction is lysine-rich and comparable in quality to that of soybean protein (Balch., 2003). Fenugreek could functionally promote health because of the high content of amino acid 4-hydroxyisoleucine which has high potential for insulin-stimulating activity (Isikli and Karababa, 2005). This high protein content and quality should be looked into in qualitative and quantitative improvement of this crop which could greatly impart population with low protein intake especially in some developing countries.

Fenugreek seeds are a good source of carbohydrates, particularly mucilaginous fiber made primarily of galactomannans. Actually, fenugreek seed is well-known for its high fiber and soluble dietary fiber content. It has 50 percent fiber, of which 30 percent is soluble and 20 percent is insoluble (Najma et al., 2011). Fiber is made up of non-starch polysaccharides in

fenugreek. The biochemical benefits of fibers present in fenugreek include: binding to toxins in the food and helps to protect the colon mucus membrane from cancer causing toxins; facilitating insulin secretion as a result of 4-hydroxyisoleucine; helping to lower rate of glucose absorption in the intestines controlling blood sugar levels and water retention capacity for easy bowel movement. Non-starchy polysaccharides increase the bulk of the food and augments bowel movements. Also, non-starchy polysaccharides assist in smooth digestion whereas high fiber of fenugreek helps in relieving constipation ailments. By preventing bile salts from being reabsorbed in the colon, fenugreek's saponins, hemicelluloses, mucilage, tannins, and pectin help lower blood levels of low density lipoprotein-cholesterol (LDL). Additionally, fenugreek husk is an excellent source of dietary fiber and phenolic acids, making it a potential source of natural antioxidants and organic components for functional meals (Naidu et al., 2011 and Mohammadi and Mortazavian, 2011).

Fenugreek is similar to other vegetables in that it contains significant levels of vitamins and minerals. It possesses some minerals in good concentrations, such as phosphorus and sulphur, but its mineral content is rather modest when compared to its vitamin content (Hegazy and Ibrahim, 2009). Fenugreek-based curry has also been found to contain high levels of calcium, iron, and zinc (Jani et al., 2009). In terms of micronutrient content, choline is particularly abundant in fenugreek. While the seed is rich in thiamin and folic acid and the leaves contain little to no folate, -carotene, a precursor to vitamin A, is present in the leaves in comparatively high amounts and is found in both the seed and the leaves at high levels of vitamin C, nicotinic acid, and riboflavin (Sharma, 1986). According to reports, fenugreek seeds include pyridoxine, cyanocobalamine, calcium pantothenate, biotin, and vitamin C. However, when fenugreek leaves are boiled in water, steamed, or fried, the vitamin C, calcium, and -carotene contents are significantly reduced (Leela et al. 2008). Therefore, it should be noted while treating materials using heat. Consuming fenugreek has been proven to potentially enhance body composition, particularly body fat percentage, and fenugreek seed's vitamin C plays a significant role in this (Poole et al., 2010).

Applications of fenugreek

General Applications andPlant Parts

In South and Central Asian nations, both ripened and unripened seeds as well as green leaves have been used as vegetables, food additives, medicinal plants, and fodder (Petropoulos, 2002). It has been used as a flavoring, spice, and curry powder, as well as a food preservative in pickles and sauces Betty (2008). Additionally, fenugreek is utilized in the paper industry, cosmetics, medicine, drinks, fragrances, paints, and several applications related to food (Table 1).

Fenugreek in Food Processing

In addition to its nutritional and nutraceutical components, fenugreek can change the texture and flavor of food. Food texture significantly affects how consumers perceive "quality" and what they chew (or "masticate"). Sensors in the mouth, the sense of hearing, and memory all provide information about texture changes to the brain, which helps create an image of the food's textural characteristics. Fenugreek has a high protein and fiber content, particularly a kind of soluble dietary fiber termed gum (approximately 20.9 g/100 g in the seed), as well as neutral detergent, which contribute to its ability to change the texture of food. Along with flavoring elements, this fiber content controls how foods' organoleptic qualities are expressed. Fenugreek serves as a stabilizer, glue, emulsifier, and gum for food processing in general (Jani et al., 2009). By eliminating the associated proteins, fenugreek gum gains in molecular weight. Fenugreek gum's viscosity rises as gum concentration rises or as the amount of linked protein is reduced. Although proteinaceous debris does not significantly affect the surface activity of fenugreek gum, residual proteins did serve a major influence in reducing the tension at the oil-water interface ((Youssef et al., 2009 and Garti et al., 1997).

Health Advantagesof fenugreek

Pharmacological and TherapeuticAdvantages

Food is undoubtedly a major determinant of human health under his own control. Apart from helping the normal body functioning and metabolism, food constituents such as antioxidants, vitamins, minerals, fiber, proteins, fat and carbohydrates also contribute to prevent overall aging and the onset of chronic diseases, in particular, metabolic disorders and oxidative damage (Mullaicharam et al., 2013). Plant-based natural antioxidants are getting popularity

among the researcher, industry and users as cure from cancer, arthrosclerotic heart disorders and other epidemics (Rababah et al., 2011). The secondary metabolites of plants origin may provide a wide range of biological and pharmacological compounds, which have been used extensively as food additives, flavorants, colorants, and as drugs and insecticides (Priya et al., 2011). Fenugreek possesses pharmacological properties such as antimicrobial, anticholesterolemic, carminative, emollient, febrifuge, laxative, restorative, uterine tonic, expectoral, galactogogue, anti-carcinogenic, anti-inflammatory, antiviral, antioxidant, demulcent and hypotensive (Moradi et al., 2013). In addition, it regulates several enzymatic activities, relieves fever, reduces body pain and fat, alleviates swelling, augments appetite and promotes lactation and sex hormones. Compounds isolated from fenugreek have remarkable biological activities including protection against cancer, malaria, allergies, bacteria and viruses (Priya, V. et al., 2011). Fenugreek, in particular, is abundant in polyphenolics that inhibit peroxidation and remarkably reduce oxidative hemolysis in human erythrocytes (Belguith-Hadriche et al., 2013). Moreover, their optimal consumption may lower triglycerides and cholesterol concentrations in the blood (Afef, 2000). Prevent cancer (Raju et al., 2004), and control diabetes mellitus (Broca, et al., 2000). The oral intake of ethyl acetate extract of fenugreek seeds has been tested to reduce triglycerides and low-density lipoprotein cholesterol (LDL-C) while increasing high-density lipoprotein cholesterol (HDL-C); hence had a noteworthy antioxidant and hypocholesterolemic effects (Belguith-Hadriche et al., 2013). Furthermore, it exhibits scavenging of freehydroxyl radical (–OH) and discourages hydrogen peroxide induced peroxidation in liver mitochondria and protects cellular organelles from oxidative damage (Kaviarasan, et al., 2007). However, hypoglycemic effect of fenugreek is likely due to the inhibitory effect of mucilaginous fiber and galactomannan gum. Currently, fenugreek is being used in pharmacology and disease treatments. A few medicinal benefits of fenugreek have been summarized in Table 2.

Antidiabetic activity

Preliminary animal and human trials suggest possible hypoglycaemic and anti-hyperlipedemic properties of fenugreek seed powder taken orally. Fenugreek has been well known to be used as antidiabetic remedy for both type I and II diabetes and has been extensively used as a source of antidiabetic compounds, from its seeds, leaves and extracts in different model systems (Khalki et al., 2010). About 25-50 g fenugreek seeds were given to diabetic patients daily in diet to prevent and manage long term complications of diabetes and studies have been made about the glycemic index of fenugreek recipes which showed that the soluble fenugreek fiber has significantly reduced the glycemic index (Sowmya and Rajyalakshmi, 1999).

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 (taken daily) can be an effective supportive therapy in the management of diabetes (Senthil et al., 2010). The bioactive compounds with respect to diabetic conditions include the galactomannan-rich soluble fiber fraction of fenugreek which may be responsible for the antidiabetic activity of the seeds (Rashmi and Rahul, 2011).

Antilipidemic activity

Fenugreek seeds have been shown to exhibit hypocholesterolemic effects, lowered serum cholesterol, triglyceride and low-density lipoprotein in hypercholesterolemia suffering patients and experimental models (Mathern et al., 2009). In obesity suffering rats fenugreek consumption in diet reduced triglyceride accumulation in the liver while fecal bile acid and cholesterol excretion were increased by fenugreek administration (Rashmi and Rahul, 2011). This may be secondary to a reaction between the bile acids and fenugreek derived saponins causing the formation of micelles too large for the digestive tract to absorb.

Antioxidant activity

Fenugreek contains phenolic and flavonoid compounds which help to enhance its antioxidant capacity (Dixit et al., 2005).It has been 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 (Altuntas et al., 2005). 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. Studies have revealed significant antioxidant activity in germinated fenugreek seeds which may be due to the presence of flavonoids and polyphenols. Furthermore, mustard and fenugreek seeds showed hypoglycemic and antihyperglycemic activity in diabetic mice and this may be due to the presence of antioxidant carotenoids in those spices (Grover et al., 2002).

Anticarcinogenic activity

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 (Bhatia et al., 2006). Diosgenin 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 of cancer. 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 (Devasena and Menon, 2003). The seed powder in the diet due to the presence of fiber, flavonoids and saponins decreased the activity of β-glucuronidase significantly and prevented the free carcinogens from acting on colonocytes whereas mucinase helped in hydrolysing the protective mucin. 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 (Sur et al., 2001). 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 (Hibasami et al., 2003). Diosgenin in fenugreek prevented cell growth and induced apoptosis in the H-29 human colon cancer cell line and fenugreek seed was found to have hepatoprotective properties (Thirunavukkarasu et al., 2003).

Table 1. Some food and non-food applications of fenugreek.

Applications	Plant Parts	References
Bread making	Seeds	Meghwal, M., Goswami, T.K., 2012
Vegetable	Leaves and stems	Balch, P.A., 2003
Food (General)	Seed and leaves (mixed with wheat and maize flour)	Srinivasan, K., 2006
Functional food	Galactomannan, fiber and extract	Meghwal, M., Goswami, T.K., 2012
Food gum	Seed	Sowmya, P., Rajyalakshmi, P., 1999
Flavoring agents	Seeds, leaves (condiments, pickles, curries)	Srinivasan, K., 2006
Forage	Leaves, straw	Sowmya, P., Rajyalakshmi, P., 1999
Cosmetics	Leaves, seeds	Meghwal, M., Goswami, T.K., 2012
Dyes	Seeds	
Paper industries	Seeds and leaves	Jani et al., 2009
Alcoholic beverages	Seeds	
Emulsifying	agent Seeds	Jani et al., 2009
Perfumes	Seed oil	Srinivasan, K., 2006
Injera Making	Seeds	Godebo DD. et al., 2019
Stabilizer and adhesive	Seeds	Meghwal, M., Goswami, T.K., 2012
Insect repellant	Seed oil	
Paints	Seeds and leaves extract	
Fumigant	Leaves	Srinivasan, K., 2006
Syrups	Trigonelline	Meghwal, M., Goswami, T.K., 2012

Table 2. Pharmacological and therapeutic benefits of fenugreek as recurrently reported

Disease/ Disorders	Description	References
Hypercholesterolemia	Anti-oxidants from seeds control high blood cholesterol	Sowmya, P., Rajyalakshmi, P., 1999
	Flavonoids from ethyl acetate extracts of seeds exhibit hypocholesterolemic abilities	Belguith-Hadriche et al., 2013
Cancer	Polyphenolic compounds from seed possess anti-carcinogenic activities	Mohamed et al., 2015
Diabetes	4-hydroxyisoleucine (amino acid) stimulates insulin production thereby control blood sugar level	Vats et al., 2002
	Polyphenolic compounds exhibit anti-diabetic effects	Kaviarasan, et al., 2007
	Curative effects of fenugreek seed powder is a potential neuropathic medicine in diabetes	Nanjundan et al., 2009
Myocardial infarction	Trigonelline (anti-oxidant) detoxification of free radicals, high lipid peroxidation and enzymes prevents Myocardial injuries	Panda et al., 2013
Skin irritation	Seeds extracts reduces the skin irritation and pain Seed powder paste produces skin healing, moisturizing, smoothening, whitening	Meghwal, M., Goswami, T.K., 2012; Sauvare et al., 2000
Indigestion and flatulence	Fenugreek has been used as laxative It stimulates appetite and act as laxative	Sauvare et al., 2000)
Inflammation	Reduces swelling and pain	Sauvare et al., 2000
	Mucilage from seed detoxify the oxidants and free radicals to reduce inflammation	Ahmadiani et al., 2001
	Anemia Prevents red blood cell oxidation	Kaviarasan, et al., 2007
	Being rich in iron (Fe) seeds are valuable to reduce anemia Restoration and Fe nutrition in iron deficiency patients	Mahmoud et al., 2012
Immunodeficiency	Natural antioxidants help to strengthen immune system Immunomodulatory and Immune stimulatory effects	Kaviarasan et al., 2004; Bin-Hafeez et al., 2003
Aging	Antioxidants improves reduces cell death and aging	Kaviarasan et al., 2004
Kidney disorders	Protects functional and histopathologic abnormalities of kidney in diabetic patients	Hamden et al., 2010
	Reduces catalase contents and superoxide dismutase activity in hypercholesterolemia patients	Belguith-Hadriche et al., 2013
	Inhibit accumulation of oxidized DNA to prevent kidney injuries	Xue et al., 2011
Others	Respiratory disorders, bacterial infection, epilepsy, gout, chronic cough, paralysis, dropsy, piles, heavy metal toxicity, liver disorders and arthritis	Belguith-Hadriche et al., 2013; Amin et al., 2005; Kaviarasan et al., 2004

Immunomodulatory effect

Immunomodulatory substance interferes with three basic areas of the immune responses directly or indirectly; the mucosal barrier function, the cellular defense function and the local or systemic inflammatory response. Research work in this effect of fenugreek is scanty but stimulatory immunomodulatory effect has been shown (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 (Raju and Bird, 2006).

Lactation Aid

Fenugreek has been reported to stimulate breast milk secretion. It is speculated that fenugreek induces sweat production and since the breast is a modified sweat gland, affect breast milk secretion (Khorshidian et al., 2016). A report summarized the anecdotal account of approximately 1200 women over 6 years, who were supplemented with commercially available fenugreek. It was used 2 to 3 capsules (580 or 610 mg), 3 times a day. It was reported that most

women experienced an increase in milk supply within 24 to 72 hours of use (Huggins, 1998).

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, reported that fenugreek seeds have hypoglycemic and hypocholesterolemic effect as supported by findings during the experiments on animals (Singh and Garg, 2006). It has been reported to improve 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 (Meghwal and Goswami, 2012).

Cholesterol Lowering Effect

Favier et al.(1995),have reported a significant decrease in blood glucose, LDL cholesterol and triglycerides of 60 individuals with diabetes, high cholesterol and triglycerides level who regularly received 25 g of fenugreek fiber powder containing nearly 50 percent fiber content. Khorshidian et al. (2016), has attributed cholesterol lowering ability of soluble fibre to bind bile acids, which are therefore excreted rather than recycled to the blood stream thus reducing blood cholesterol. Basch et al. (2003), have reported that fenugreek seeds have ability to lower serum cholesterol, triglyceride and low-density lipoprotein in hypercholesterolemia suffering patients and experimental models. Singhal et al., have also reported hypocholesterolemic effects of fenugreek seeds (Singh and Garg, 2006).

Biochemical Advantages: benefits on enzyme activity and metabolic syndrome

The term "metabolic syndrome" refers to the grouping of various cardiovascular and metabolic risk factors, such as dyslipidemia, hyperglycemia, and elevated blood pressure; the basic characteristics of these clusters are abdominal obesity and insulin resistance Chew et al., 2006). Numerous intricate biochemical pathways are involved in the genesis of the metabolic syndrome. Numerous hypothesized mechanisms relating the symptoms have all been linked to potential impairments of normal cardiovascular function. Increased levels of non-esterified fatty acids, LDL, reactive oxygen species (ROS), and lipotoxicity may be connected to insulin resistance (Van Gaal et al., 2006). It has been suggested that inflammation is a key factor in the development of metabolic syndrome symptoms, and that the pro-inflammatory state associated with obesity and metabolic syndrome is likely brought on by consuming too many calories from a high-carbohydrate diet (Govindarajan et al., 2008). Numerous bioactive mediators, such as pro-inflammatory cytokines, are released by adipose tissue, and these mediators not only affect body weight homeostasis but also alter blood vessel structure and function, glucose and lipid metabolism, blood pressure, coagulation, and inflammation, which results in atherosclerosis and endothelial dysfunction (Van Gaal et al., 2006). Quantifying the accumulation of particular metabolites or the modification of the enzyme activity related biochemical pathways in question is common and occasionally regular.

The ability of fenugreek to restore to some extent the actions of key enzymes in particular lipids and carbohydrate in human subject and animal model has been widely reported (Yadav et al., 2004). Fenugreek administration in rats restored the changed enzyme activities and partially normalized hyperglycemia (Baquer et al., 2011). Altered levels of superoxide dismutase, 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 (Baquer et al., 2011). Furthermore 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. While fenugreek seed polyphenol extract administered per day reduced the levels of lipid peroxidation products and protein carbonyl content, it promoted mode of action of antioxidant enzymes, and restored content of thiol groups; this shows a high antioxidant capacity of fenugreek. 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 found to decrease significantly in liver diabetes as compared to those of control (Yadav et al., 2004).

Improvements to crops and research

Fenugreek is one of the potential candidates to be acclimatized under stress regions or on However; [38], reported successful cultivation of fenugreek under saline sodic soils followed by Farahmandfar et al (2013), who made efforts to facilitate fenugreek cultivation by seed priming. In addition, several experiments to check fenugreek's drought tolerance potential and genotypic screening of available landraces for drought stress (Ahari et al., 2009; 2010). One step ahead, advocated the efficient use of rhizobial inoculation for fenugreek and claimed a fruitful improvement in its adoption to arid and semiarid soils, but unfortunately no further research was made for rhizobial inoculations (Ali et al., 2012).

Moreover, fenugreek was investigated for heavy metal toxicity (Elleuch et al., 2013), sowing date (Nandre et al., 2011), intercropping (Shirzadi et al., 2011), phosphorous fertilizer doses (Jat et al., 2012), and response to exogenous application of plant growth regulators (Danesh-Talab et al., 2014). More recently, fenugreek as intercrop, a living mulch, to suppress weeds and found significant results (Pouryousef et al., 2015).

Estimation of genetic variability is important for improvement of any crop, but in spite of fenugreek's diverse importance and applications, genetic diversity among fenugreek genotypes has rarely been estimated (Harish et al., 2011).

Furthermore, genetic variability and its association with yield and yield component characters were studied by (Jain et al., 2013). Harish et al., used random amplified polymorphic DNA and inter-simple sequence repeat for molecular and biochemical characterization of ten accessions (Harish et al., 2011). In recent times, mutagens have become important tools in crop improvement. These mutagens are being used to produce resistance in various crops to improve their yield and quality traits. Basu, who initiated mutation facilitated breeding in fenugreek through ethylmethane sulfonate for seed quality and production (Basu, 2006).

Study gaps

Inference: Medical research has thoroughly investigated the possible benefits of fenugreek on human health. But without a doubt, it only makes up a small portion of this plant with many potential medical uses. Fenugreek is believed to have a significant genotypic range because it is geographically widespread and grows well in a variety of climates. Furthermore, because it is a crop that has not undergone extensive breeding (artificial selection), there is a chance that it may have a variety of potential allelic defenses against environmental pressures. Despite the fact that science is unstoppable and is currently advancing considerably more quickly than at any other time in its history, fenugreek unfortunately received little attention.

Fenugreek deserves to be taken into consideration in large-scale research programs that study not just its potential but also prospective improvements. To find the possible genes that could aid in breeding programs, followed by targeted mutation and genetic improvement for abiotic stress tolerance, a comprehensive genomic and agronomic characterization/clustering is required. Additionally, fenugreek has to be investigated and supported, especially in arid agricultural systems, as a green manuring and fodder crop as well as for soil reclamation.

Conclusion

Fenugreek's liberal usage is safe and it has a number of potential health benefits. Since ancient times, fenugreek has reportedly been used as a medicine and is unquestionably thought to be safe for human health. Fenugreek has promise nutritional and health benefits due to its abundance in fiber, protein, and bioactive components. Fenugreek can be suggested and added to our regular diet based on these therapeutic capabilities, which are supported by scientific research. Additionally, this crop has the potential to retain a respectable position in agricultural systems due to its tolerance for drought, salinity, and heavy metals, as well as its broad adaptability to different climatic areas and marginal soils. Unfortunately, there have only been a few improvements to crops so far. Therefore, there is still a large gap, especially in varietal development and more specifically in breeding that is aided by biotechnology.

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