Review Article

Phytotherapeutic, Phytonutraceutic, Medicinal, Food and Forage Properties of Fenugreek (*Trigonellafoenum-graecum* Linn.): A Wonder Herb of Multifarious Values

Comment [A1]: Suggestion: Phytotherapeutic, Nutraceutical, Medicinal, and Forage Properties of Fenugreek (*Trigonellafoenum-graecum* Linn.): A Comprehensive Review

ABSTRACT

Fenugreek (*Trigonellafoenum-graecum*L ~~inn.~~) is an annual herb belongingto the family Fabaceae. It is one herb with versatile and varied economic value in the national and international markets. Fenugreek is cultivated as a winter crop in many states of India, specifically Andhra Pradesh, Chhattisgarh, Gujarat, Haryana, Madhya Pradesh, Punjab, Rajasthan, Telangana, and Uttaranchal. So far as its economic value is concerned, it has been used in Ayurveda, a traditional Indian system of medicine for treating various human and animal ailments. Its green leaves are consumed as vegetable and make "parathas" and seeds in many dishes like Biscuits, Laddoo, tadka, Sprouts etc. In Rajasthan and Punjab,the fenugreek crop is sown mainly to feed the cattle as green/dry fodder. Being a member of Fabaceae, its root nodules help in the fixation of atmospheric nitrogen to nitrate, which increases nitrogen fixation and restoressoil fertility. Fenugreek seeds and leaves have a wide range of effects that are believed to protect the human body from several diseases. This review article discusses various properties such as anti-diabetic, anti-cancer, anti-inflammatory, antioxidant, anti-ulcer, anti-fertility, immunomodulating, etc. Its high fiber, protein and several bioactive compounds make fenugreek a natural and healthpromoting herb.

Key words: Economic importance; ethnobotany fenugreek;phytotherapeutics, phytonutraceutic;Trigonellafoenum-graceum.

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1. INTRODUCTION

According to World Health Organization (WHO) report, out of more than 400 families of medicinal plants, 315 occur in India. Thus, the availability of traditional knowledge and resources makes India a potential leader in the future pharmaceutical industry [1]. There is an

urgent need that the knowledge of Charaka (1stcentury BCE), Sushruta (6th Century BCE), Vagbhata (6thcentury AD) and other Ayurvedic seers be tapped and delivered to the populace using the productivation methodology currently available.

In India, fenugreek (*Trigonellafoenum-graecum Linn.*),popularlyknown as "methi" is a legume seed spice and medicinal herb belonging to the family Fabaceae.The fenugreek plant is an erect annual herb. Trigonella signifies 'little triangle' because of its yellowish-white triangular blossoms [2]. Some common regional names of this plant are hayseed (English), Hulba (Arabic), Moshoseitaro (Greek), Shoot (Hebrew) and mukhmeshampeet (Persian), methika (Sanskrit), methiya (Kannad), menticura (Telugu) Uluva (Malayalam). Fenugreek is one of the most established winter crops under cultivation in Asia 4000 BC. It has been postulated that itscentre of origin could be the Indian sub-continentas it is broadly cultivated in India and other neighbouring Asian nations [3]. In India, fenugreek is cultivated for human consumption as well as forage, fodder,seed and green manure[4,5]. Dry seeds of fenugreek havea strong aroma and slight bitterness in taste. These are utilized as flavours, seasoning, preservatives, spice and flavouringagent for pickles, sprouts, curry, and vegetables to improve the flavour, aroma and nutritive value. These seeds arerich in fiber, gum and other phytonutrients. Extracts from fenugreek seed include diosgenin, saponin and have phytotherapeutic potential[6]. Fenugreek can potentially suppress microbial infections[7,8] in companion crops,humans, and animals.Ithas additionally been assessed for green manure for its nitrogen fixing potential[99,10]. The high fiber, gum and proteinpresent in seeds are used as a food stabilizer, additive and emulsifier.Extracts of fenugreek seed containing galactomannan areutilized as nutrients, industrial thickeners and therapeutic purposes[11,12,5]. Fenugreek is anessential dietary part of Indian flavours and is utilized to improve health because of the expectancy of medical advantages. Fenugreek is notable for using in nourishment to forestall ailments such as intestinal gas, cramps, swelling, acid reflux, diabetes, malignant growth, hypertension, joint inflammation, liver problems and numerous different illnesses and disorders. Because of the significant levels of cell reinforcement mixes,antioxidants, bioactive compounds, phenols, flavonoids, and anthocyanin, different tests and clinical preliminaries have demonstrated that fenugreek can fight pathologic conditions, particularly for the treatment and avoidance of perilous sicknesses, for example, diabetes, few malignant growths, contaminations and gastrointestinal disorders.

To utilize the medicinal properties of fenugreek at its full potential,demand is increasing over time to develop the products with new clinical proofs. Fenugreekis treated as a decent contender for traditional and ayurvedic drugs as it has phenolic compounds, bioactive amino acids, glycosides and cancer prevention agent activities. Despite the unique logical and clinical profile of fenugreek, consumer understanding is still in its adolescence and growers/promoters of this spice need to concentrate on this significant economic and commercial obstacle. However, in recent years, good number of research and publications have been published on the yield and economics, fertility and biofertilizer effect on quality and productivity[13], nutritional value and uses[14], fodder bank[15], protein structure[16], molecular characterization[17] andorganic production[18] of fenugreek to understand its more roles in medical uses.

Agrobiodiversity occupies a unique place within the overall realm of biodiversity. It refers to diversity among crops, cultivation systems, agro-ecosystems, horticulture, animals, birds, insects and microorganisms. Plant genetic diversity within cultivated crops is a key component of agricultural production systems. To ensure sustainable agriculture in diverse agro-ecosystems while implementing good agricultural practices and new livestock systems to intensify agriculture and alleviate increasing pressures on natural ecosystems. Conserving naturally available resources and plant diversity should be a priority. Traditional crops such as fenugreek have the potential to be conserved if they are tied to the economic development of farmers[19].

2. BOTANY AND MORPHOLOGY

Fenugreek is an annual herbwith 2n = 16 chromosome numbers. The plantis an erect, hairy, cylindrical, branched medium height (30-80cm) and has root nodules on branched tap root. The pod of this plant contain around 16 to 20 tiny, yellowish-dark coloured, sweet-smelling, and impactful seeds (Fig. 1). Leaves comprise three lobed contrarily applaud pamphlets with short petioles, serrated edges and oval stipules[20]. Flowers; 1-2 axillary, sessile, bracteate, zygomorphic, corolla much exerted, white or creamy-white. The pods of fenugreek contain around 16 to 20 small, sweet-smelling, and impactful grains/seeds. Fenugreek seeds are yellow to greenish-brown, rhomboidal, flat, 5-8mm long with a deep groove across one corner. It is cultivated as a cold-season seed spice and fodder crop,mainly in north-western India.It is grown during winter (October to April) and flowersduring January-February and March-April. Its leaves are used mainly as vegetables, fodder and seeds for pot-herbmedicinal properties.

3. NUTRITIONAL CONSTITUTES OF HERB

Fenugreek's high nutritional value makes it suitable for various applications, including vegetables, food, beverages, nutraceuticals, pharmaceuticals, flavour and fragrance, and several industrial uses. Trigonelline, nicotinic acid, and other alkaloids are found in the stem etc[21]. Rao [22] reported that fenugreek leaves contain seven saponins known as glechnins, which are chemically glycosides of diosgenin. Leaves contain approximately 86.1% water, protein (4.4%), fat (0.9%), minerals (1.5%), fiber (1.1%), and sugar (6%). Leaves are a rich source of minerals such as calcium, phosphorus, magnesium, zinc, iron, and major amino acids such as riboflavin, thiamine and niacin.It was found that crunchy fenugreek herb contained 220.97 mg of ascorbic acid per 100 g of leaves and β-carotene 19 mg/100 g. Young leaves have excellent nutrient retention, so eating them raw or cooked can help you lose weight[23].

4. QUALITY PARAMETERS OF FENUGREEK SEEDS

Fenugreek seeds are the most valuable part of the plant. The seeds are generally golden yellow and have a maple flavour but a bitter taste. Seeds are fibrous, sticky and rubbery [24].Fenugreek contains many chemical compounds, including steroidal sapogenins. A diosgenin component was found in the oily germ of fenugreek[25].Table 1 depicts the nutritional and pharmaceutical components of fenugreek.

Table: 1 Major Nutrients, carbohydrates, vitamins and mineral properties of fenugreek seed (value /10g)

Major Nutrient	**Value g/10 g**	**Vitamins**	**Value mg/10 g**
Total Calories	32.30	Vitamin A	6.00
Calories from Fat	5.40	Vitamin B_1	0.04
Total Fat	0.60-0.79	Vitamin B_2	0.03
Protein	2.30	Vitamin C	0.30
Total Carbohydrate	5.80	Thiamin	0.03
Water	0.24-0.88	Riboflavin	0.04
Dietary Fiber	2.40	Niacin	0.16
Mucilage	86.10	Vitamin B6	0.06
Fat, Lipids & Fatty Acids	**Value g/10 g**	Folate (mcg)	5.70

Saturated fat	150.00	β-carotene	0.96
Total fatty acid content (%)	4.50 - 7.00	**Minerals**	**Value mg/10 g**
Palmitic acid	53.00	Calcium (Ca)	17.60
Oleic acid	73.00 – 117.00	Iron (Fe)	3.30
Linoleic acid	225.00 – 360.00	Magnesium (Mg)	19.00
Linolenic acid	110.00 -175.00	Phosphorus (P)	30.00
Steric acid	27.00	Potassium (K)	77.00
Free fatty acids	0.01	Sodium (Na)	6.70
Monoacylglycerols	0.01	Zinc (Zn)	0.25

Source: USDA Nutrient Database. mg/10g- mili gram per 10 gram; g/10g-gram per 10 gram

5. CONSTITUENTS SEEDS AND OIL

Seeds are a rich source of gum, oil, amino acids, tryptophan and lysine, dietary fiber, alkaloids, and flavonoids. The seed gum is composed of galactose and mannose[21].The seeds also contain alkaloids such as trigonelline, gentianine, and calpain[26]. The bitter taste of fenugreek seeds is due to the presence of oils, steroidal saponins and alkaloids. It is rich in trace elements (Ca, Cu, Fe, Zn, K, Mg, P, Na, Mn), Vitamin A, B1 and C, sitosterol, n-alkanes, sesquiterpenes and cholesterol[27, 28].

The scent dynamic mixes dependent on the fenugreek fragrance identification with the assistance of Gas Chromatograph and these incorporate the olfactometrydiacetyl, 1Octene-3-one, sotolon, acidic corrosive; 3-Isobutyl-2-methoxypyrazine, butanoic corrosive, isovaleric corrosive, 3-isopropyl2-methoxypyrazine, caproic corrosive, eugenol, 3-Amino-4,5dimethyl-3, linalool, (Z)-1,5-Octadiene-3-one, 4-dihydro-2 (5H)- Furanone with trademark smell of rich like roasty/natural, metallic, sharp, paprika like, sweat-soaked/foul, flowery, smelly, zesty respectively. The extract containing trigonellineand trigonellic acid is useful as a hair growth stimulant. (Table:2).

In recent years there has been a marked increase in medicinal plants worldwide. The burgeoning problem due to modern medical treatments, methods, and harmful side effects of those drugs has attracted the general public attention, especially medical scholars. In a country

where a large majority of people live in villages, live below the poverty line, and cannot afford expensive medical care, it poses a severe threat to the health of ordinary men[29].

6. PHARMACOLOGICAL ACTIVITIES FOR HUMAN HEALTHCARE

In the history of fenugreek, it has been used for various reasons by ancient Egyptians and played a role in both herbal medicine and religious practices. In Greece, fenugreek is still used as animal feed. Thus, the Latin name for fenugreek *Trigonellafoenum-graecum*means 'hay' in Greek. Thousands of years ago, herbaceous plants were highly valued in the cultures of Egypt, China, India, Arab countries, the Roman Empire, and Greece.Because of its role in health care, the functional food industry has classified it as a potential dietary supplement. Much research has been done on therapeutic effects and compound identification. The pharmacological actions of fenugreek,such as antioxidant, anti-cancer, gastroprotective, antidiabetesantirheumatic, etc.,are discussed below (Table 2 & 3).

6. 1 ANTIOXIDANT EFFECTS

Oxidative damage to proteins and lipids is caused by the overproduction of reactive oxygen species, leading to chronic degenerative diseases. Several studies have suggested fenugreek as a potential antioxidant[29].The protective effects of fenugreek demonstractedagainst lipid peroxidation and enzymatic antioxidants in cyclophosphamide-treated mice by assessing the extent of lipid peroxidation and the presence of antioxidantsin the bladder of mice [30].Fenugreek contains many essential nutrients, and this makes it a potent antioxidant.Supplementing the diet with fenugreek seeds decreased lipid peroxidation, increased glutathione and beta-carotene levels, and decreased alpha-tocopherol levels. This study shows that impaired free radical metabolism can be normalized by dietary fenugreek seed supplementation [31].A study showed that fenugreek showed the greatest superoxide and radical scavenging effect and it was concluded that the antioxidant activity was related to high phenolic content in fenugreek [32].

6.2 ANTI-DIABETIC EFFECT

Fenugreek seed powder solution remarkably improved lipid metabolism in patients with Type II diabetes. Fenugreek seeds may offer a new option for treating type II diabetes. Fenugreek seed contains about 0.5-0.1.0% 4-Hydroxy-Isoleucin that helps the s stimulation of insulin secretion.

Apart from that, the main saponin compound of fenugreek is diosgenin, which can inhibit cholesterol absorption and lower cholesterol levels in the liver. The extract showed significant activity against alloxan-induced diabetic conditions. The effective dose of 1 g/kg, is lower than any standard anti-diabetic drugs available in the markets. The hypoglycemic effect of the extract was compared with that of the anti-diabetic glimepiride. The extract 4 mg/kg single dose showed significant activity against alloxan-induced diabetic conditions. The most effective dose recognized was 1 g/kg, lower than standard anti-diabetic drugs [33].In another study, a fenugreek seed was included in the diet of normal and diabetic hypercholesterolemic dogs. The defatted fraction containeddietary fiber (54%) andsteroidal saponins (5%) reduced plasma cholesterol levels, glucagon and blood glucose, from pretreatment levels in dogs in both groups. The cholesterol-lowering effect was replicated in rats. Administration of high-fiber fractions of fenugreek lowered critical parameters, including total cholesterol, triglycerides, and low-density lipoproteins in diabetic rats [21].

6.3 ANTI-CANCER EFFECT

Cancer is becoming one of the major diseases worldwide, and it is the second leading cause of death worldwide after cardiovascular disease. Conventional cancer treatments only add a few months or years to a patient's life and cause significant side effects. Fruits and vegetables act as an alternative medicine and their active constituents are suggested for cancer treatment. Several plant-based anti-cancer drugs like vinca alkaloids (vinblastine and vincristine), epipodophyllotoxins (etoposide and teniposide), taxanes (paclitaxel and docetaxel), camptothecin derivatives (camptothecin and camptothecins) are available in the market.It is reported that the incidence of colon cancer can be reduced by including fenugreek seed powder in a diet [34].A study revealed that fenugreek seed extract showed cytotoxic activity to inhibit the development of MCF-7 cells.Such effectshave not been observed in livercancer cell lines. These results highlight that the effects of fenugreek seed extract directly depend on the cancer cell type [35]. In another study, different normal and cancer cell lines were exposed to different concentrations of fenugreek extract (100 µg/ml, 200 µg/ml, and 300 µg/ml) and different time points (0, 24, 48, 72, and 96 hours). Selective cytotoxic effects of fenugreek extract have been observed to act against various cancer cell lines, including T-cell lymphoma under *in vitro* conditions[36]. Some researchers proved that dietary intake of fenugreek seeds containing diosgenin could prevent

azoxymethane-induced colon cancer during the initiation and acceleration phases. These *in vitro* experiments o cancer cellsdemonstrated that diosgenin present in fenugreek seedsinhibited cell proliferationand induced apoptosis in the human colon cancer cell line HT-29 in a dose-dependent manner [37].

6.4 ANTI-INFLAMMATORY AND ANTI-ARTHRITIC EFFECT

The body's defencemechanism, inflammation, is a complex biological response of vascular tissue to potentially harmful external or internal stimuli, including pathogens, chemicals, foreign substances and xenobiotics [38].The lysosomal enzymes cause inflammatory disease release of the lysosomal enzyme, which stimulates prostaglandin synthesis. Petroleum ether was for extraction from fenugreek seed powder by cold maceration. This fenugreek seed petroleum ether extract (FSPEE) was analyzed by gas-liquid chromatography (GLC). Treatment with 0.5 ml/kg FSPEE reduced carrageenan- and formaldehyde-induced paw inflammation by 37% and 85%. A biphasic increase followed by a decrease in paw volume has been observed in CFA-induced arthritis. In rats treated with FSPEE (0, 5 ml/kg), cotton pellet weight was reduced by 42.5% and reduction in higher SGPT and ALP activities in serum and liver. Therefore, due to the presence of linoleic acid and linoleic acid, the fenugreek seed petroleum ether extract exhibits significant anti-inflammatory and anti-arthritic effects (39].A study recorded an anti-inflammatory effect of fenugreek extract, which showed thatrats were treated with a single dose (100 or 200 mg/kg). Inhibition of inflammatory swelling was 45% and 62% in the lower and higher dose groups, respectively, compared to 100% in untreated rats [39].

6.5 ANTIGASTRIC EFFECT

Gastroprotective means any substances that have the ability for the prevention or amelioration of injury to the gastrointestinal tract.The role of fenugreek seeds and omeprazole in ethanol-induced gastric ulcers has been studied. The results showed that the aqueous extracts and gel fractions isolated from the fenugreek seeds exhibited significant antiulcer protective effects. The cytoprotective effects of seeds appeared to be due not only to their antisecretory activity but also to their effects on mucosal glycoproteins[40].

6.6 HEPATOPROTECTIVE AND NEPHROPROTECTIVE EFFECTS

Drugs or substances that have a beneficial effect on the liver are understood to be hepatoprotective. Sodium nitrite is one of the synthetic food additives that humans are constantly exposed to.Increased consumption of nitrite-treated products is directly related to the development of tissue damage, hepatotoxicity and nephrotoxicity. Hepatotoxicity and chronic liver injury from various causes are severemetabolic disorders that affect people of all ages [41]. A studywas conducted on 40 rats in which rats were randomly assigned (10 per group) to control (physiological saline solution), fenugreek (150 mg/kg/day), $NaNO_2$ (80 mg/kg/day), and $NaNO_2$+fenugreek (80 mg/kg/day + 150 mg/kg/day) groups.This group was offered fenugreek seed extract two hours before $NaNO_2$. After three months, the rats were decapitated and blood, kidney and liver tissues were removed for the study.Results suggested that exogenous fenugreek mitigates $NaNO_2$-administration-induced hepatotoxicity and nephrotoxicity. Fenugreek extract exerted antioxidant and anti-inflammatory effects and played an essential role in preventing liver and kidney damage from chronic administration of NaNO2 [42].This study demonstrated fenugreek seeds' healing and protective effects against cisplatin-induced liver injury in rats at 5% and 10% levels of fenugreek supplementation.Another study investigated the defensive effect of aqueous extract of fenugreek against carbon tetrachloride-induced hepatotoxicity in rats. A 4% aqueous fenugreek extract enhanced the detrimental effects of carbon tetrachloride and normalized all biomarkers tested to control values. It has been concluded that it protects against liver damage caused by carbon tetrachloride. Results confirmed that carbon tetrachloride increased the antioxidant activity of serum transaminases, liver lipid peroxidation and liver enzymes [43].

6.7 ANTIBACTERIAL AND ANTIFUNGAL EFFECTS

Researchers have studied the various plants for antibacterial properties for decades in hopes of developing new treatments, including fenugreek. Botanical and microbial species use and the extraction method, influence the antimicrobial potency and severity [29]. Fenugreek seeds are known to be nutritious and good for digestion and it is commonly used as a spice to flavour curries and other recipes. In Ayurveda, the traditional Indian medicine, fenugreek seeds were used to treat many gastrointestinal ailments.In a study, different concentrations of 125, 250, 500, and 1,000 µG/ml fenugreek seed ethanol extract were used against bacteria. Most of the bacteria (*Staphylococcus aureus, Pseudomonas aeruginosa, Salmonella typhi, Proteus mirabilis,*

Escherichia coli and *Vibrio parahaemolyticus*) were inhibited at a minimum inhibitory concentration of 50 µg/ml. These results are significant due to the small amount of fenugreek seed extract required to inhibit bacterial growth[35].The fenugreek seed extract was investigated and found effective in controlling the growth of Aspergillus flavus, Trichodermaviridiae and Trichophyton rubrum when applied at 250 µg mL^{-1}[30].

6.8 INFERTILITY EFFECT

No studies have confirmed whether fenugreek seeds cause fertility or infertility.Several studies on fenugreek seeds have shown that fenugreek seeds have anti-implantation and anti-fertility effects and have abortion effects in rats. The dose of Fenugreek seeds of 1 g/kg/day orally reduces male fertility by lowering testosterone and sperm concentrations and inhibiting sperm mass and individual motility[44].The presence of steroidaloestrogen-like saponinsmay cause a negative effect on serumtestosterone and semen quality that ultimately acts as anti-fertility agent [45]. High dietary levels of fenugreek significantly reduce fertility in both male and female rabbits, reduce testis weight, and cause obvious damage to seminiferous tubules and interstitial tissue [46].The extract also showed weak estrogenic activity in immature ovariectomized rats. All observations indicate that fenugreek saponin extract has anti-fertility effects. Saponin extracts were found to be more effective in anti-implantation and abortion activities. The extract also showed weak estrogenic activity in immature ovariectomized rats. It shows that the substance has an anti-fertility effect [47]. The estrogenic effects exhibited by saponin extracts from fenugreek may be due to the presence of diosgenin, yamogenin-3 and tigogenin [48].

6.9 WEIGHT LOSS

Repeated administration of fenugreek seed extract slightly but significantly reduced dietary fat intake in healthy overweight individuals. These botanical components justified that fenugreek seed aqueous extracts effectively inhibited fat accumulation and ameliorated dyslipidemia in obese rats on a high-fat diet (HFD). This happened due to increased insulin sensitivity, glucose and lipid metabolism, antioxidant defense and downregulation of lipogenic enzymes [49].Significant weight loss was observed in mice with a high concentration of fenugreek (1%). Fenugreek seed extract effectively reduces body and adipose tissue weight dose-dependently[50]. In another study, fenugreek seed proteins, galactomannans, and polyphenols

have been previously reported to modulate dyslipidemia in obese and diabetic rodents[51].Further studies are needed to investigate fenugreek and other anti-obesity mechanisms.

Table 2: Proximate composition of fenugreek and their healthcare benefits

Chemical constituents	Effective against	Reference
Trimethylamine, Neurin, Trigonelline, Choline, Gentianine, Carpaine and Betain	Hypoglycemic, antinociceptive, anti-inflammatory	[52,53]
vitexin, Tricin, Quercetin, naringenin, rutin, isovitexin, Antioxidant	santi-inflammatory	[52,53,54, 55,56]
Isoleucine, 4-Hydroxyisoleucine, Histidine, Leucine, lysine, L-tryptophan, Arginine	Diabetes Mellitus,	[57]
diosgeninGraecunins, fenugrin B, fenugreekine, trigofoenosides A–G	Diabetes, hypercholesterolemia	[58,59,60]
Gum, neutral detergent fiber	Digestion, constipation, heart problems, insulin response	[61,62,63,64]
Triacylglycerols, tocopherols, sterols, free fatty acids.	Low Cholesterol	[63]
Caryophyllene	Essential oil, used in food products, bioactive properties	[64]
Trichloroacetic acid, pentadecyl ester	Used in cosmetic treatments	[65]
Phytol	Used in antioxidant, anti-inflammatory, antibacterial, anti-asthma, anti-cancer, and personal care products to produce synthetic forms of vitamin E and vitamin K1, also used in sexual and urological disorders, bioactive	[66,67,68]
Quinoline	Antiasthmatic, Antitussive, and Antibacterial agents are bioactive and also used for urinary disorders.	[69,70]
Tetradecane	Drugs for disorders of the nervous	[71,72]

	system, antioxidants, antibiotics, and antiseptics also used as food additives, bioactive properties	
Diosgenin	Suppressed tumour mass and volume of cancer cells, Induced cytotoxicity; Diminished tumour growth; Inhibited proliferation, migration, and invasion	[73,74,75]
Protodioscin	Induced reduction of cell growth and increased apoptosis	[76]

Table 3: Doses and concentrations of fenugreek products and compounds

Compounds/products	Concentration	References
Diosgenin	1-10 µM	[77]
4-Hydroxyisoleucine	5-200 µM	[78, 79]
Trigonelline	40 mg/kg (diet)	[80]
Fenugreek seed extract (FSE)	100 mg/kg	[81]
Fenugreek seed powder	9 g/kg (diet), 3%	[81,82]

7. FENUGREEK AS FODDER FOR ANIMALS

Animal components are the backbone of Indian agriculture in arid and semi-arid regions of the country.Round the year availability of diverse green fodder is paramount to provide balanced nutrition and fiber rich diet to animals (small, medium and large) for their better growth, development and yields (milk, dung, wool). Feeding fenugreek grain to cattle has been a common practice for ages in Indiato avoid stomach-related problems and improve animal milk quality.Based on three week study with dairy cows, have shown that dietary fenugreek grains (20% ofdry diet matter)increased milk yield and concentration of mostof the functional fatty acids while reducing the blood cholesterol concentrationin milk withoutaltering milkflavour ortaste [83].One study concluded that fenugreek fed to crossbred Damascus goats resulted in significantly higher serum prolactin and increased milk production compared to the control. This may be mediated by prolactin hormone stimulation. Goats fed 60 g/day of fenugreek seed powder had significantly higher milk yields than the control group (1236 vs 1093 ml/day)of goat [84].

Fenugreek constitutes high-quality nutritious feed for dairy cattle, improving livestock's health status[15] because of agood combinationof bioactive components (flavonoids,polyphenols, proanthocyanidins).Fenugreek grains and shoots could be an alternative option to enrich animal feed's biological and nutritional value in case of the unavailabilityof regular green fodder like lucerne and berseem. Fenugreek, a legume with a very good composition ofbiologicallyactive components, represents differently in various anatomic parts.Supplementing animalfeed with fenugreekcould prevent birth abortion and better management of babies during lactation in cows, buffaloes and other animal models(Table:4).

Table 4. Significance of Fenugreek as fodder for animals

Animal used for the study	Beneficial role	References
Buffaloes	A feed rich in ground fenugreek seed (GFS) enhanced total dry matter (13.17–14.00 kg/day) and milk output (7.34–8.01 kg/day) in Anatolian water buffaloes (AWBs). Adding fenugreek seeds (1.5%) to the feed of Surti buffaloes increased milk output while improving sensory attributes.	[85,86]
Dairy cow	Fenugreek seed feeding increased milk's functional fatty acid profile, decreased blood cholesterol levels (4% more than the control diet), and reduced cholesterol levels in milk (1.48 vs. 1.83 mg/g milk lipid).	[83]
Goat	Aecrease in goat milk fat owing to fenugreek seed supplementation at very high doses. Interestingly, there was a positive trend in the flavour and palatability of boiling milk, indicating that fenugreek supplementation had a beneficial impact on milk quality. Fenugreek supplementation improves milk output, plasma constituents and growth hormone levels in goats	[87,84]
Rabbits	Fenugreek seed gum (FSG) may be considered a prebiotic. It is based on its resistance to pre-caecal digestion and favourable influence on thecaecal	[88,89]

	bacteria population. Combining fenugreek seeds and probiotics enhanced growth performance, nutrient digestibility, and serum hormones without affecting carcass parameters in either male or female developing rabbits.	
Broiler chicken	The addition of seeds to the diet raised plasma concentrations of total protein and globulin. Supplementation of diets with a mixture of fenugreek and black cumin improved body weight gain, FCR, Hb, PCV, serum proteins, and serum cholesterol levels. 1 percent fenugreek powder for 38, 15 and 42 days produced significantly higher BW and BWG than the control groups of chicks.Fenugreek seed extract (FSE) is replace antibiotics to improve broiler health and growth and it increases chicken production while ensuring chickenquality and health. The optimal concentration of 100 mg/kg forFSE has been initially found.	[81,90,91, 92]

mg/g; Kg/day-kilogram per day; BW-Body weight; BWG-body weight gain; FCR-feed consumption ratio; Hb-Hemoglobin; PCV-packed cell volume.

8. PRECAUTIONS

As per Ayurveda, fenugreek seeds may not be appropriate for individuals with the 'Pitta' body type since it is probably builds the 'Pitta' side effects, heat sensation and heat creation in the body. Because of this impact, a few people experience expanded perspiring after consuming fenugreek seeds. The most common side effects of fenugreek are loose stools when it is consumed for the first time,excessive use can cause runs, perspiring problems, a headache, apprehension, quick heartbeat, insecurity, untimely labour and premature delivery, stomach agitation and sometimes swelling. This may cause allergy symptoms like skin rash, tingling, swelling of face, tongue, or throat swelling, dizziness and trouble breathing. Fenugreek seeds have hot potency and produce a heat sensation in the body. Hence, Fenugreek seeds contradict

bleeding issues since seeds may promote bleeding. Then again, fenugreek leaves have inverse activity because of their cool intensity. Leaves appease Pitta Dosha and reduce bleeding, as indicated by Ayurveda. Hence other than normal cooking diets, it is very much necessary to consume this medicinal plant with the advice of some Ayurvedacharya or doctor for its better results without any side effects.

9. CONCLUSION

The properties of plants in the Indian tradition were discovered differently than in Western science. This is described in traditional textbooks as "Dravya-Guna-Shastra" (the science of the properties of materials). The challenge for Indian scientists is to build cross-cultural bridges between Dravya-guna-shastra and modern pharmacology. Such bridges can only be built if mutual respect exists and scientists feel they own indigenous knowledge and modern science. Though there are sufficient research data and literature available for fenugreek use and its benefits to prove this crop one of the best medicinal, easily indigenously available wonder herb and multipurpose crop with traditional values in pharmaceutical, nutraceutical, feed, fodder and industrial applications but still there exists a big gap to fill by the knowledge and for scientific research to gain the attention of the world to this medicinal seed spice crop. This low volume high-value, nutritionally rich, nutraceutical important, multipurpose plant has a huge potential and applications in the cuisines and feed, medicines, cosmetics and nutraceuticals and pharmaceutical industries. This review will be for end users to improve their health, improved immunity in human beings and higher milk production with good health in cattle. Looking to its diverse effects and variable constituents, it is very much required to do screening of available germplasm for its medicinal and aromatic contents available in variable amounts. It requires some in-depth scientific experiments to fix its medicinal products as readily available and safe consumable form so that the products may reach every end user and be used efficiently. This plant contains medicinal alkaloids, steroidal compounds and sapogenins, and many uses of this plant are mentioned in traditional medicine. The clinical use of fenugreek can be attributed to the abundant chemical constituents that fenugreek possesses. Since bioactive compounds have a promising future in disease-curing natural products, further research and research will be conducted to isolate bioactive compounds from crude extracts for drug development.

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Comment [A4]: The reference style is inconsistent, and some references are incorrect or incomplete. Please review and correct all references to ensure they are formatted correctly.

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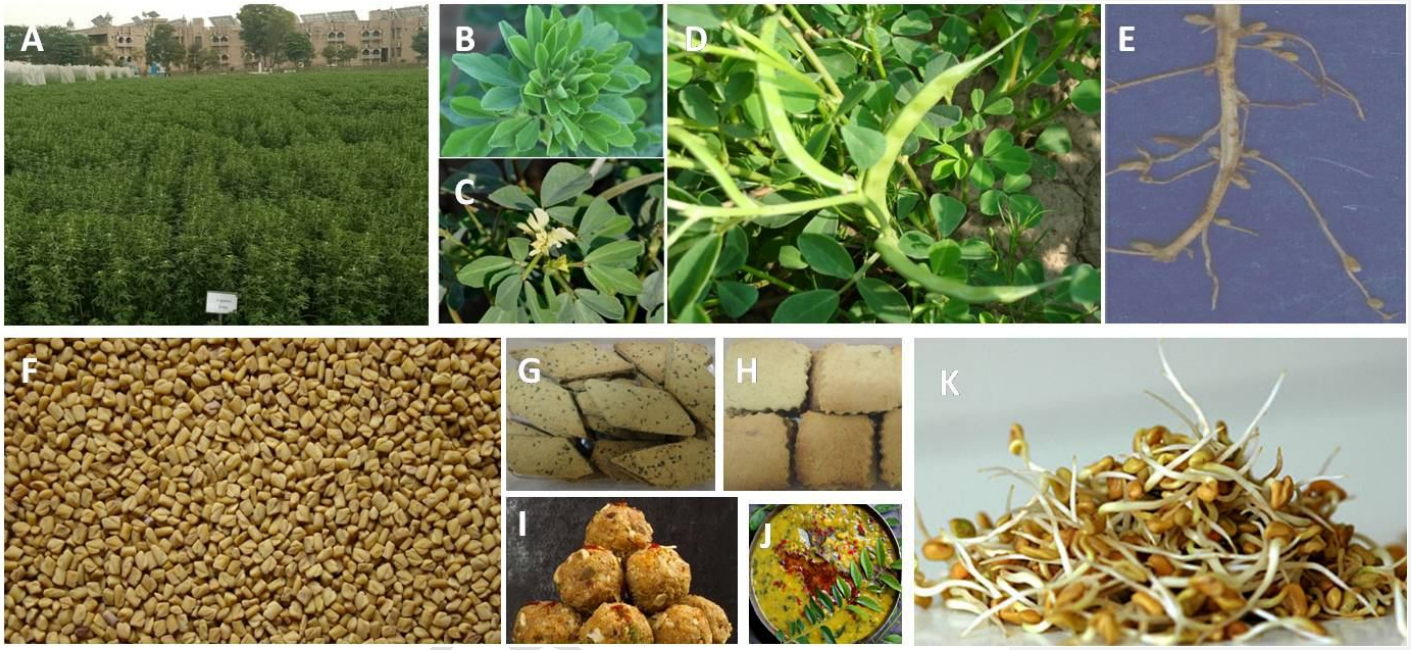

Fig. 1- Fenugreek (*Trigonellafoenum-graecum* Linn.) (A) Field view of fenugreek crop at ICAR-NRCSS, Ajmer, (B) Bunch of leaves, (C) Flowering stage, (D) Pod in fenugreek, (E) Root nodules of fenugreek, (F) Mature seed, (G-K) Products of fenugreek: (G) Salty Biscuits, (H) Sweet Biscuits, (I) Laddoo, (J) Daaltadka and (K) Sprouts.