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COMPREHENSIVE REVIEW OF FENUGREEK'S ACTIVE CONSTITUENTS AND THEIR PHYSIOLOGICAL EFFECTS ON THE HUMAN BODY

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ABSTRACT;

Fenugreek (Trigonella Foenum-graecum L.) well known herb used in culinary and traditional medicine and nutrition for its wide ranging therapeutic properties , is a yearly plant (Fabaceae family) and it is primarily winter crop across several states in India its seeds and leaves are rich in health promoting constituents such as diosgenin, 4-hydroxyisoleucine, trigonelline, saponins, and flavonoids. These compounds are primarily responsible for fenugreek's diverse biological effects . It is especially noted for its antidiabetic action, helping to regulate blood glucose and improve insulin function. additionally, fenugreek supports cardiovascular health by lowering cholesterol and triglyceride levels.

Its *anti-inflammatory, antioxidant, and digestive –protective effects* make it beneficial for managing chronic inflammatory and GI conditions. Fenugreek is also widely used as a *natural galactagogue* to enhance breast milk production in lactating women. Due to its phytoestrogenic compounds, it may help in balancing hormones and alleviating menstrual-related symptoms. Furthermore, recent studies highlight its *antimicrobial, anticancer, and neuroprotective* potential, supporting its use in complementary health strategies . Collectively , fenugreek represents a promising botanical agent with broad pharmacological applications and functional food values.

KEYWORDS; Fenugreek (Trigonella foenum graecum), Flavonoids, Trigonelline, Galactagogue, Ayurveda.

INTRODUCTION;

According to the World Health Organization (WHO) report, India is haven for 315 out of more than 400 recognized families of medicinal plants. This rich biodiversity, coupled with the availability of traditional knowledge systems such as Ayurveda, Siddha, and Unani, positions India as a potential global leader in the future pharmaceutical industry. Ancient Ayurvedic texts by seers like Charaka and Sushruta offer valuable insights that can be modernized for current health solutions. Fenugreek (Trigonella foenum-graecum), commonly known as methi, is a leguminous herb from the Fabaceae family, widely cultivated in India for its culinary and medicinal uses. Its seeds are rich in fiber, protein, and bioactive compounds like saponins and diosgenin, offering antioxidant, antimicrobial, and therapeutic properties. Traditionally used for treating ailments like diabetes, digestive issues, and inflammation, fenugreek also serves industrial roles as a stabilizer, emulsifier and thickener. Fenugreek has strong medicinal potential due to its rich bioactive and antioxidant content, making it valuable in traditional and Ayurvedic medicine. However, limited consumer awareness and economic barriers hinder its broader use. Recent research has focused on its nutrition, cultivation and therapeutic properties. Preserving traditional crops like fenugreek through sustainable practices and linking them to farmers' income can support both health and biodiversity. [(1)]

Fig(1) : Leaves of fenugreek **(2) : seeds of fenugreek**

BOTANICAL DESCRIPTION;

Fenugreek is a winter-season annual herb with 16 chromosomes, the erect plant grow up to 80 cm tall with branched stems and root nodules. It produces small, aromatic seeds inside pods and white to creamy flowers,the slender beaked pods measuring 3-15cm in length and each pod containing 10-20 oblong greenish brown seeds. Fenugreek enriches the soil by fixing atmospheric nitrogen. The plant is self-pollinating and the greens are harvested at the three to four leaves stage , when the saponin content increases and bitterness intensifies, while seeds are collected 30-35 days after flowering or roughly 155-165 days after sowing mainly grown in north-western India for its seeds, leaves, and use as fodder [(1)]

CONSTITUTENTS OF HERB;

Fenugreek is highly nutritious and used in foods, beverages, nutraceuticals, and pharmaceuticals. Its stems contain alkaloids like trigonelline and nicotinic acid, while the leaves are rich in saponins, especially diosgenin glycosides. Leaves are composed of 86% water and provide protein, fiber, minerals, and essential vitamins like riboflavin, thiamine, and niacin. They also contain high levels of ascorbic acid (220.97 mg/100g) and β-carotene (19 mg/100g). Young leaves retain nutrients well and are beneficial for weight management when eaten raw or cooked.Fenugreek seeds are a nutritionally dense and bioactive-rich food ingredient with a diverse composition of beneficial compounds;

GUM CONTENT;

Fenugreek seed gum is predominantly composed of galactomannan, featuring a galactose-to-mannose ratio of about 1;1, which results in high water solubility and hydration properties. This makes fenugreek gum valuable for food and pharmaceutical applications as a thickener, emulsifier, and stabilizer[(7)(8)] .

MACRONUTRIENTS;

Seeds comprise 45–60% carbohydrates (with mucilaginous galactomannan fiber making up a significant portion), 20–30% proteins (high in essential amino acids like tryptophan and lysine), and 5–10% fixed oils. The oils are especially rich in linoleic, linolenic, and oleic acids[(7)(8)] .

ALKALOIDS;

Fenugreek's characteristic bitter taste and aroma come from alkaloids such as trigonelline (the most abundant), gentianine, and carpaine (sometimes transliterated as calpain). Trigonelline is especially notable for its health-promoting effects[(8)] .

STEROIDAL SAPONINS AND FLAVONOIDS;

The seeds contain saponins (notably diosgenin), cholesterol, sitosterol, and several flavonoids, including quercetin, vitexin, and apigenin derivatives. These contribute to the seeds' medicinal and antioxidant activities[(8)] .

VITAMINS AND MINERALS;

Fenugreek seeds are a good source of trace elements (calcium, copper, iron, zinc, potassium, magnesium, phosphorus, sodium, manganese) and vitamins A, B1 (thiamine), B2 (riboflavin), B6, C, niacin, and folic acid[(8)] . For example, iron content in seeds is exceptionally high, along with substantial amounts of magnesium and copper[(7)(8)]

VOLATILE AND AROMATIC COMPOUNDS;

Using gas chromatography, researchers have found a range of compounds contributing to fenugreek's complex aroma, such as;

- Diacetyl
- 1-octen-3-one
- Sotolon (responsible for the "maple syrup" note)
- 3-isobutyl-2-methoxypyrazine
- Butanoic, isovaleric, and caproic acids
- Eugenol, linalool, furanones, and other terpenes

These generate unique sensory attributes described as roasty, earthy, metallic, sharp, paprika-like, flowery, and occasionally pungent.

HEALTH BENEFITS AND HAIR GROWTH;

Trigonelline and trigonellic acid have been explored for stimulating hair growth, both topically and orally. Patents and preliminary studies suggest they enhance blood flow to hair follicles, delivering nutrients and potentially increasing hair thickness, length, and pigmentation. The effect is further enhanced when combined with vitamin B6, a key hair nutrient.Beyond hair growth, fenugreek's bioactive compounds show diverse therapeutic effects; antidiabetic (diosgenin, trigonelline), antioxidant, anti-inflammatory, and possible neuroprotective actions.

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

Major Nutrient	Value g/10g	vitamins	Value mg/10g
Total calories	32.30	Vitamin A	6.00
Calories from fat	5.40	Vitamin B1	0.04
Total fat	0.60-0.79	Vitamin B2	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 fibre	2.40	Niacin	0.16

Mucilage	86.10	Vitamin B6	0.06
Fat, Lipids & Fatty acids	**Value g/10g**	Folate(mcg)	5.70
Saturated fat	150.00	Beta-carotene	0.96
Total fatty acid	4.50-7.00	**minerals**	**Value mg/10g**
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
Linoleinic 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

EFFECTS OF FENUGREEK;

ANTIOXIDANT EFFECTS;

Excessive production of reactive oxygen species (ROS) can lead to oxidative damage of lipids and proteins, which is a key factor in the development of chronic degenerative diseases. Research has indicated that fenugreek possesses significant antioxidant properties [(21)] .In animal studies, particularly in cyclophosphamide-treated mice, fenugreek demonstrated protective effects by reducing lipid peroxidation and enhancing antioxidant enzyme activity. These effects were evaluated by examining the level of lipid peroxidation and antioxidant presence in the bladder tissue of the mice [(22)] .Fenugreek is rich in vital nutrients, which contribute to its antioxidant potential. When included in the diet, fenugreek seeds were shown to;

- Reduce lipid peroxidation
- Elevate glutathione and beta-carotene levels
- Lower alpha-tocopherol concentrations

These findings suggest that fenugreek supplementation can help restore disrupted free radical metabolism[(23)] Additionally, fenugreek exhibited strong superoxide and free radical scavenging activity in one study, with its high phenolic content believed to play a key role in this antioxidant capacity.

ANTI-DIABETIC EFFECT;

Fenugreek seed powder has demonstrated a significant ability to enhance lipid metabolism in individuals with Type II diabetes, indicating its potential as a natural therapeutic agent for managing the condition. One of its bioactive compounds, 4-hydroxyisoleucine (present at 0.1–0.5%), plays a key role in stimulating insulin secretion.

Additionally, diosgenin, a major saponin found in fenugreek, has been shown to reduce hepatic cholesterol levels by inhibiting its absorption. In experimental models, fenugreek extract exhibited notable hypoglycemic activity in alloxan-induced diabetic conditions. A single dose of 4 mg/kg of the extract produced significant effects, comparable to the standard anti-diabetic drug glimepiride, while a dose of 1 g/kg was found to be the most effective, outperforming conventional treatments [(24)] .

Further evidence comes from studies in diabetic and normal hypercholesterolemic dogs, where dietary inclusion of fenugreek seeds led to marked reductions in plasma cholesterol, glucagon, and blood glucose levels. The defatted seed fraction, rich in dietary fiber (54%) and steroidal saponins (5%), was primarily responsible for these effects.

Similar outcomes were observed in diabetic rats, where the administration of high-fiber fenugreek fractions significantly reduced total cholesterol, triglycerides, and low-density lipoprotein (LDL) levels, highlighting fenugreek's potential in managing both diabetes and associated lipid disorders .

ANTI-CANCER;

Effect Cancer is a major global health concern and the second leading cause of death after cardiovascular disease. Current treatment options generally prolong survival by only a short period and often cause considerable side effects. As a result, attention has shifted toward plant-based alternatives, as many fruits and vegetables contain bioactive compounds with potential anticancer properties. Several plant-derived drugs, such as vinca alkaloids (vinblastine, vincristine), epipodophyllotoxins (etoposide, teniposide), taxanes (paclitaxel, docetaxel), and camptothecin derivatives, are already used in clinical practice.

Dietary inclusion of fenugreek seed powder has been reported to lower the risk of colon cancer [(25)] . In one study, fenugreek seed extract showed cytotoxic effects against MCF-7 breast cancer cells, while no such activity was observed in liver cancer cell lines, suggesting that its effects depend on cancer cell type [(26)] .

Another investigation exposed different normal and cancer cell lines to fenugreek extract at concentrations of 100, 200, and 300 µg/ml for 0, 24, 48, 72, and 96 hours. The results revealed selective cytotoxicity toward certain cancer cells, including T-cell lymphoma, under in vitro conditions [(27)] . Some researchers have also indicated that diosgenin present in fenugreek seeds may play a preventive role in cancer development.

ANTI-INFLAMMATORY AND ANTI-ARTHRITIS;

Inflammation is a defense mechanism of the body, representing a complex biological reaction of vascular tissues to potentially harmful internal or external factors such as pathogens, chemicals, foreign substances, and xenobiotics [28] . Lysosomal enzyme release plays a crucial role in inflammatory conditions by triggering prostaglandin synthesis. Fenugreek seed petroleum ether extract (FSPEE), prepared from seed powder via cold maceration and analyzed using gas–liquid chromatography (GLC), demonstrated notable anti-inflammatory effects. At a dose of 0.5 ml/kg, FSPEE reduced carrageenan- and formaldehyde-induced paw swelling by 37% and 85%, respectively. In complete Freund's adjuvant (CFA)-induced arthritis, paw volume initially increased in a biphasic manner before declining. FSPEE-treated rats also showed a 42.5% reduction in cotton pellet granuloma weight, along with lower serum and liver levels of serum glutamic pyruvic transaminase (SGPT) and alkaline phosphatase (ALP).

The anti-inflammatory and anti-arthritic activities are attributed mainly to the presence of linoleic and linolenic acids [39]. Another study further confirmed these effects, reporting that single doses of fenugreek extract (100 or 200 mg/kg) reduced inflammatory swelling by 45% and 62%, respectively, compared to untreated controls [29] .

HEPATOPROTECTIVE AND NEPHROPROTECTIVE EFFECTS;

Hepatoprotective agents are compounds that help maintain liver health and function. Sodium nitrite ($NaNO_2$), a widely used synthetic food additive, is consumed regularly through processed foods and has been linked to tissue injury, hepatotoxicity, and nephrotoxicity. Chronic liver injury caused by various factors is a serious metabolic disorder affecting individuals across all age groups [30] .

A study involving forty rats divided into four groups (control, fenugreek 150 mg/kg/day, $NaNO_2$ 80 mg/kg/day, and $NaNO_2$ + fenugreek 80 mg/kg/day + 150 mg/kg/day) evaluated the protective potential of fenugreek. The extract was administered two hours before $NaNO_2$ exposure. After three months, liver, kidney, and blood samples were examined. Results indicated that fenugreek significantly reduced $NaNO_2$-induced liver and kidney toxicity by exerting antioxidant and anti-inflammatory effects, thereby preventing chronic organ damage [31] .

Additional research confirmed that dietary fenugreek supplementation (5% and 10%) could protect against cisplatin-induced liver injury in rats. Similarly, aqueous fenugreek extract (4%) was effective against carbon tetrachloride (CCl_4)-induced hepatotoxicity, restoring biomarker levels close to normal. CCl_4 exposure elevated serum transaminases, lipid peroxidation, and liver enzyme activity, all of which were markedly reduced with fenugreek treatment [32] .

ANTIGASTRIC EFFECT;

Gastroprotective agents are compounds that help prevent or reduce damage to the gastrointestinal tract. The effects of fenugreek seeds and omeprazole have been examined in ethanol-induced gastric ulcer models. Studies showed that both the aqueous extract and gel fraction of fenugreek seeds produced marked anti-ulcer activity. These protective effects were linked not only to the seeds' ability to inhibit gastric acid secretion but also to their capacity to enhance mucosal glycoprotein content.

INFERTILITY EFFECT;

Although no definitive studies confirm whether fenugreek seeds enhance or impair fertility, several animal studies indicate that they possess anti-implantation, anti-fertility, and abortifacient properties. In rats, oral administration of 1 g/kg/day of fenugreek seeds reduced male fertility by lowering testosterone levels, decreasing sperm concentration, and impairing sperm viability [16] . These effects are thought to be related to steroidal estrogen-like saponins, which can adversely affect serum testosterone and semen quality, thereby acting as anti-fertility agents [17] .

In rabbits, high dietary intake of fenugreek significantly lowered fertility in both males and females, reduced testicular weight, and caused notable damage to seminiferous tubules and interstitial tissue [18] . Weak estrogenic activity of fenugreek extract has also been observed in immature ovariectomized rats. Saponin-rich extracts were particularly effective in producing anti-implantation and abortifacient effects [19] . These estrogenic activities are believed to be due to the presence of diosgenin, yamogenin-3, and tigogenin [20] .

WEIGHT LOSS;

Regular administration of fenugreek seed extract has been shown to slightly but significantly reduce dietary fat intake in healthy overweight individuals. In animal studies, aqueous extracts of fenugreek seeds effectively inhibited fat accumulation and improved dyslipidemia in obese rats fed a high-fat diet (HFD). These effects were attributed to enhanced insulin sensitivity, improved glucose and lipid metabolism, increased antioxidant defense, and suppression of lipogenic enzyme activity [13] .

In mice, high dietary concentrations of fenugreek (1%) led to significant weight reduction, with the extract lowering both body and adipose tissue weight in a dose-dependent manner [13]. Additionally, fenugreek seed proteins, galactomannans, and polyphenols have been reported to modulate dyslipidemia in obese and diabetic rodent models [14] . However, further research is required to fully elucidate the anti-obesity mechanisms of fenugreek.

FENUGREEK AS FODDER FOR ANIMALS;

In the arid and semi-arid regions of India, livestock plays a vital role in agriculture, and a continuous supply of diverse green fodder is essential to ensure

balanced nutrition and fiber intake for animals of all sizes, supporting their growth, health, and productivity in terms of milk, dung, and wool. Fenugreek grains have long been fed to cattle to improved digestion and enhance milk quality.

A three-week trial with dairy cows found that including fenugreek grains at 20% of the dry matter in the diet increased milk yield, improved the concentration of beneficial fatty acids, and lowered blood cholesterol levels in milk, without affecting its flavor or taste [(12)] . In another study, crossbred Damascus goats supplemented with fenugreek showed higher serum prolactin levels and milk production compared to controls. Goats receiving 60 g/day of fenugreek seed powder produced significantly more milk (1236 ml/day) than the control group (1093 ml/day) [(11)] .

Fenugreek is considered a nutritious feed source for dairy cattle due to its rich composition of bioactive compounds such as flavonoids, polyphenols, and proanthocyanidins [(15)] . Its grains and shoots can serve as an alternative to conventional green fodders like lucerne and berseem when these are unavailable. As a leguminous plant with varied bioactive content in different plant parts, fenugreek supplementation in livestock diets may also help prevent abortions and support better calf management during lactation in cattle, buffaloes, and other animal species [(1)] .

GALACTAGOGUE EFFECT;

Fenugreek is among the most commonly used galactagogues by breastfeeding mothers. Its seeds are believed to activate hormone precursors, which may result in enhanced milk production. This action is thought to be linked to the presence of phytoestrogens and diosgenin, a steroidal sapogenin, in fenugreek. Although the precise mechanism is not fully established, two explanations have been proposed. One suggests that fenugreek promotes sweat secretion, thereby stimulating milk output since the mammary gland is essentially a modified sweat gland. The other proposes that phytoestrogens and diosgenin directly support increased milk flow and supply.The generally recommended dosage is 2–3 capsules (each containing 580–610 mg), taken 3–4 times per day, with therapy

discontinued once an adequate milk supply is achieved. Many mothers report improvement within 24–72 hours of starting supplementation [(9)]

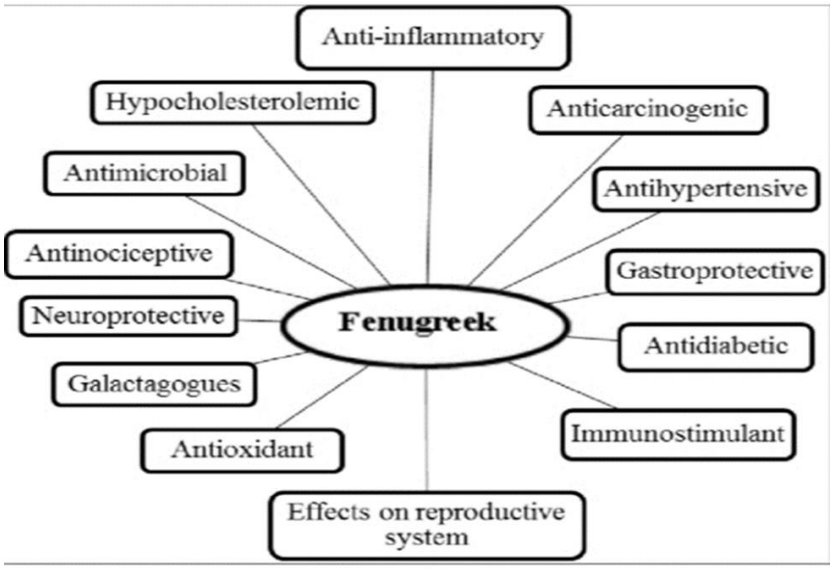

Figure 3: effects of Fenugreek

PRECAUTION;

In Ayurveda, fenugreek seeds are generally discouraged for individuals with a Pitta body constitution, as they can aggravate Pitta-related symptoms, including a rise in body heat and heat sensation. This warming property may also cause some people to sweat more than usual after consumption. Initial intake may occasionally result in loose stools, while excessive consumption can trigger diarrhea, excessive sweating, headaches, restlessness, rapid heartbeat, unsteadiness, stomach discomfort, or bloating. In certain instances, fenugreek has been linked to premature labor and miscarriage. Allergic responses are also possible, with symptoms such as skin rashes, itching, swelling of the face, tongue, or throat, dizziness, and breathing difficulties.

Because fenugreek seeds possess ushna virya (hot potency) and can increase heat in the body, they should be used in controlled amounts and only under the guidance of a qualified Ayurvedacharya or healthcare provider.

Fenugreek seeds are not recommended for individuals with bleeding disorders, as they may enhance bleeding. In contrast, the leaves possess cooling properties and exhibit the opposite effect. In Ayurvedic practice, fenugreek leaves are used to pacify Pitta Dosha and help manage bleeding. Therefore, beyond their role in everyday cooking, the plant should be consumed only under the supervision of an Ayurvedacharya or qualified medical professional to maximize benefits and minimize potential side effects[(1)]

CONCLUSION;

In Indian traditional medicine, the understanding of plant properties follows a different approach from Western science, known as Dravya-Guna-Shastra—the study of the inherent qualities of substances. A major task for Indian researchers is to establish meaningful links between Dravya-Guna-Shastra and modern pharmacology, which can only be achieved through mutual respect and a shared sense of ownership of both traditional knowledge and contemporary science.

Although ample research and literature highlight the diverse benefits of fenugreek—positioning it as a highly valuable, easily available medicinal herb with uses spanning pharmaceuticals, nutraceuticals, animal feed, fodder, and industrial applications—a considerable gap still exists in translating this traditional wisdom into globally recognized scientific evidence.

Fenugreek is a nutrient-rich, low-volume, high-value crop with multiple uses in food, medicine, cosmetics, and the pharmaceutical and nutraceutical industries. It supports human health and immunity and enhances milk yield and overall wellness in livestock. Given its varied bioactive profile, systematic screening of available germplasm for medicinal and aromatic constituents is essential, followed by rigorous studies to produce standardized, safe, and easily consumable medicinal forms.

This plant contains alkaloids, steroidal compounds, and sapogenins, with numerous uses documented in traditional systems of medicine. Fenugreek's potential in addressing non-communicable diseases makes it suitable for preventive as well as therapeutic applications. As a common spice, it can be seamlessly incorporated into everyday diets.its clinical value lies in its abundance of active phytochemicals, warranting further research to isolate bioactive molecules from crude extracts for future drug development[(1)]

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