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Yemeni Fenugreek and Its Nutritional and Health Effects, Narrative Review

Tariq Al-Samai[1], Mohammed Alsebaeai[1,2*], Mohammed- Al-qarwani[1] and Mansour Ghaleb[1]

[1]Department of Clinical Nutrition and dietetics, Faculty of Medicine and Health Sciences, University of Sciences and Technology, Sana'a City, Yemen
[2]Department of Food Science and Technology, Faculty of Agriculture and Food Science, IBB University, Yemen

**Corresponding author*

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A B S T R A C T

Fenugreek (*Trigonella foenum-graecum* L.) is a multifunctional herb of the Fabaceae family, widely cultivated across the Mediterranean, North Africa, Asia, and Europe. Yemeni fenugreek is traditionally valued for its unique nutritional and bioactive composition. This narrative review synthesizes evidence on its chemical profile, health benefits, culinary applications, and safety. The seeds are rich in proteins, carbohydrates, dietary fiber, essential vitamins and minerals, and bioactive compounds, including diosgenin, trigonelline, 4-hydroxyisoleucine, saponins, and flavonoids, which confer antidiabetic, hypolipidemic, antioxidant, and anti-inflammatory effects. Clinical trials and meta-analyses demonstrate improvements in glycemic control and lipid profiles, while its high fiber and gum content facilitate diverse functional food applications. Reported adverse effects mainly gastrointestinal disturbances, allergic reactions, and potential drug interactions highlight the need for cautious use. Comparative data suggest Yemeni fenugreek may offer superior bioactivity, though further longitudinal and region-specific studies are required to substantiate traditional claims and optimize its therapeutic and functional food potential.

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is an annual herbaceous plant belonging to the Fabaceae family that has been cultivated for centuries across the Mediterranean region, North Africa, Asia, and parts of Europe (Ruwali *et al.,* 2022). This versatile plant is widely recognized for its medicinal and nutritional properties, serving as a spice, vegetable, and therapeutic agent in various traditional medicine systems (Badraoui *et al.,* 2025). The plant's seeds are particularly valued as a rich source of bioactive compounds, including diosgenin, trigonelline, 4-hydroxyisoleucine, galactomannan, saponins, alkaloids, and flavonoids, which contribute to its documented hypoglycemic, hypocholesterolemic, antioxidant, antibacterial, anti-

inflammatory, and anticancer activities (Almatroodi *et al.,* 2021; Branch, 2013; Laila & Murtaza, 2015).

The global increase in non-communicable diseases has heightened interest in plant-based interventions, positioning fenugreek as a promising candidate due to its bioactive profile and health-promoting potential (Paramanik *et al.,* 2025). However, its composition and efficacy are influenced by geographical origin and cultivation practices, which affect its nutritional and therapeutic value (Zhang *et al.,* 2025). Yemeni fenugreek, traditionally regarded for its distinctive qualities, may possess unique biochemical and nutritional characteristics (Zaid *et al.,* 2024). Despite its cultural and practical significance, comprehensive scientific investigations of this variety remain limited. Studying Yemeni fenugreek is essential to validate traditional claims, support the development of functional foods and nutraceuticals, and guide future research.

A narrative literature search was conducted across PubMed, Scopus, Web of Science, and Google Scholar for studies published between January 2000 and December 2025. Keywords and Boolean operators were used to identify relevant literature, including terms such as “fenugreek,” “Trigonella foenum-graecum,” “Yemeni fenugreek,” “nutritional composition,” “bioactive compounds,” “antidiabetic,” “hypolipidemic,” “phytochemicals,” and “health benefits.” Reference lists of selected articles were manually screened to identify additional studies. This narrative review aims to summarize the nutritional composition, bioactive compounds, and health benefits of Yemeni fenugreek. It evaluates evidence from preclinical and clinical studies on its antidiabetic, hypolipidemic, antioxidant, and anti-inflammatory effects, highlights its unique properties compared to other regional varieties, and identifies gaps for future research and functional food applications.

Botanical Classification

Fenugreek *(Trigonella foenum-graecum L.)* is a member of the Trifoliate tribe within the Fabaceae family and the Papilionaceae subfamily (Balodi, 1991). It is believed to have originated in the Mediterranean region of the “Old World” (Heinisch, 1965) and has historically been used to treat various human ailments. This multipurpose legume is cultivated for its seeds, which serve as a spice, in artificial flavoring, hormone production, and green manure (Duke, 2012) Fenugreek seeds are also traditionally used to enhance lactation (Chantry *et al.,* 2004), provide high-protein animal feed, and improve soil fertility through nitrogen fixation, reducing the need for chemical fertilizers (Upadhyaya *et al.,* 2006). Globally, fenugreek is grown as a summer crop under diverse agro-climatic conditions in countries including China, India, Egypt, Ethiopia, Morocco, Ukraine, Pakistan, Greece, and Turkey (Zaid *et al.,* 2024).

In Yemen, it is cultivated primarily under rain-fed conditions in the northern, southern, and central highlands over approximately 4,031 hectares, yielding around 1.03 tons per hectare However, low productivity and sensitivity to adverse conditions have led farmers to prioritize cash crops, resulting in limited local production that does not fully satisfy consumer demand, as fenugreek seeds are a key ingredient in the traditional Yemeni dish, saltah (Zaid *et al.,* 2024)

Historical Background and Traditional Uses

The historical significance of fenugreek spans millennia, with documented use dating back to ancient Egyptian, Greek, and Roman civilizations (Hilles & Mahmood, 2021; Petropoulos, 2002). Throughout the Middle Ages, fenugreek was introduced into Central and Western Europe, partly by Arab physicians and later by Benedictine monks, for its medicinal and aromatic properties (Schauenberg & Paris, 1980). Its cultivation and application subsequently spread throughout Asia and Africa, where it remains an integral component of traditional medicine and culinary practices.

Among the various regional varieties, Yemeni fenugreek holds particular interest due to its distinctive biochemical composition and potential therapeutic superiority. Recent comparative analyses have revealed significant differences in the nutritional profiles of fenugreek seeds from Yemen compared to those from other regions, suggesting that geographical factors including soil composition, climate, and cultivation practices may substantially influence the concentration of bioactive compounds (Al-Sebaeai *et al.,* 2017a) Yemeni fenugreek specifically demonstrates advantageous levels of key phytochemicals responsible for its medicinal properties, positioning it as a subject of considerable scientific and commercial interest.

Fenugreek boasts a rich historical legacy as one of the oldest known medicinal plants, with documented use spanning thousands of years across diverse civilizations. The earliest recorded evidence of fenugreek utilization

dates back to ancient Egypt approximately 1500 BC, where it was mentioned in the Ebers Papyrus as a treatment for various digestive and reproductive disorders (Hilles & Mahmood, 2021). The ceremonial significance of fenugreek in ancient Egyptian culture is further evidenced by the discovery of its seeds within the tomb of Tutankhamun, indicating its role in religious rituals and burial practices (Petropoulos, 2002).

The plant was subsequently cultivated in ancient Greece and Rome, where it was valued as a food source, spice, and fodder crop. The species name "foenum-graecum" translates to "Greek hay," reflecting its historical use as forage in the Mediterranean region (Petropoulos, 2002). Greek and Roman physicians documented various therapeutic applications of fenugreek, particularly highlighting its efficacy in treating inflammatory conditions and promoting wound healing. Throughout the Middle Ages, fenugreek was introduced into Central and Western Europe through two primary channels: Arab physicians who incorporated it into their medical practices, and Benedictine monks who cultivated it in monastic gardens for its medicinal and aromatic properties (Schauenberg & Paris, 1980). This period witnessed the integration of fenugreek into formal medical traditions, with documented use for aiding lactation, improving digestive function, and managing metabolic disorders.

In traditional Ayurvedic medicine, fenugreek has been employed for centuries as a therapeutic agent for diabetes, hyperlipidemia, and digestive ailments. Similarly, in Traditional Chinese Medicine, it has been used as an antifungal, anti-inflammatory, and antidiabetic remedy (Yao *et al.,* 2020). The global dissemination of fenugreek continued through trade routes, eventually establishing it as a staple in various culinary traditions, particularly in South Asian, North African, and Middle Eastern cuisines.

In Yemen specifically, fenugreek has long been incorporated into traditional health practices, where it is commonly consumed as a tea or powder to address gastrointestinal complaints, regulate blood sugar, and support women's health. The traditional knowledge surrounding Yemeni fenugreek has been passed down through generations, with specific cultivation and processing techniques potentially contributing to its distinctive phytochemical profile. This historical continuum of use, from ancient civilizations to contemporary traditional medicine, underscores the enduring therapeutic value of fenugreek while providing a foundation for scientific investigation into its pharmacological properties.

Chemical Composition of Fenugreek Seeds

Macronutrient Profile

Fenugreek seeds represent a rich source of macronutrients, including proteins, carbohydrates, and fats, with compositional variations observed between different regional varieties. The seeds typically contain 25-35% protein, 45-60% carbohydrates, and 5-10% fixed oils, alongside substantial dietary fiber content (Bienkowski *et al.,* 2017; Khorshidian *et al.,* 2016). Comparative analyses have revealed significant differences in the nutritional profiles of Yemeni fenugreek seeds relative to those from other regions.

A comprehensive investigation by (Al-Sebaeai *et al.,* 2017b) documented distinct variations between Yemeni and Saudi fenugreek seeds. Yemeni seeds contained 8.91% moisture, 5.69% crude fat, 14.81% crude protein, 12.97% crude fiber, 3.53% ash, and 54.09% total carbohydrates. In comparison, Saudi seeds demonstrated slightly higher moisture (10.23%) and total carbohydrates (56.39%), but lower crude fat (3.54%) and crude fiber (11.24%). Crude protein (15.34%) and ash (3.26%) content were relatively similar between the two sources. These compositional differences highlight the influence of geographical origin on fenugreek's nutritional profile, potentially attributable to variations in soil composition, climate conditions, and cultivation practices.

The protein fraction of fenugreek seeds is particularly noteworthy for its high lysine content, with quality comparable to soybean protein (Mandal & DebMandal, 2016). The amino acid 4-hydroxyisoleucine constitutes 20-30% of total protein and exhibits significant insulin-stimulating potential (Işıklı & Karababa, 2005). Protein content varies depending on the seed fraction, with the endosperm containing approximately 43.8 g of protein per 100 g, while whole seeds contain around 25.4 g per 100 g (Mathur & Choudhry, 2009; Naidu *et al.,* 2011). Fenugreek protein concentrates demonstrate promising functional properties, including high oil absorption (1.56 ml/g), water absorption (1.68 ml/g), and bulk density (0.66 g/ml), with solubility optimized in both acidic (pH 4.5) and alkaline (pH 12) conditions (El Nasri & El Tinay, 2007).

Vitamins and Minerals

Fenugreek seeds contain an impressive array of essential vitamins and minerals that contribute significantly to their nutritional and therapeutic properties. The vitamin profile includes Vitamin A (1040 IU), Vitamin C (12 mg), Niacin (6 mg), Pyridoxine or Vitamin B6 (0.6 mg), Thiamine or Vitamin B1 (0.41 mg), Riboflavin or Vitamin B2 (0.36 mg), Nicotinic acid (1.1 mg), and Folate (57 µg) per 100 g of seeds (Khorshidian *et al.,* 2016) These vitamins function as essential cofactors in numerous metabolic processes, supporting antioxidant activity, energy production, and overall physiological homeostasis.

The mineral composition of fenugreek seeds is equally notable, containing substantial quantities of calcium (176 mg), iron (33.5 mg), zinc (2.5 mg), phosphorus (296 mg), magnesium (191 mg), manganese (1.22 mg), and selenium (6.3 µg) per 100 g of seeds (El Nasri & El Tinay, 2007; Jani *et al.,* 2009). These minerals play critical roles in bone health, enzymatic function, oxygen transport, and antioxidant defense mechanisms. The significant iron content positions fenugreek as a potential dietary intervention for addressing iron deficiency, while the substantial magnesium and zinc concentrations support numerous biochemical processes essential for human health.

Bioactive Compounds

Fenugreek seeds contain a diverse spectrum of bioactive compounds responsible for their therapeutic properties. The most significant of these include steroidal sapogenins (primarily diosgenin), alkaloids (mainly trigonelline), the unique amino acid 4-hydroxyisoleucine, galactomannan-soluble fiber, and various flavonoids and polyphenols (Almatroodi *et al.,* 2021; Laila & Murtaza, 2015). These compounds operate through multiple mechanisms to exert antidiabetic, hypocholesterolemic, antioxidant, and anti-inflammatory effects.

The soluble fiber fraction, particularly galactomannan, constitutes a substantial portion (20-30%) of fenugreek seeds and forms a viscous gel in the gastrointestinal tract that slows carbohydrate absorption and inhibits cholesterol reabsorption. This mucilaginous fiber binds bile acids, reducing fat absorption and cholesterol levels while modulating intestinal flora through prebiotic effects (Mohammadi & Mortazavian, 2011). Fenugreek husk, rich in dietary fiber and phenolic acids, offers potential as a natural antioxidant and functional food ingredient (Naidu *et al.,* 2011).

The saponin compounds, including diosgenin, contribute to fenugreek's hypocholesterolemic effects by forming complexes with cholesterol and bile acids in the gut, increasing their fecal excretion (Kandekar *et al.,* 2022). Meanwhile, the alkaloid trigonelline and the amino acid 4-hydroxyisoleucine demonstrate significant antidiabetic properties through insulin-sensitizing effects and stimulation of insulin secretion from pancreatic β-cells (Tak *et al.,* 2024). The collective action of these bioactive compounds establishes fenugreek as a multifaceted therapeutic agent with applications in managing metabolic disorders.

Health Benefits and Therapeutic Potential

Antidiabetic Effects

Fenugreek seeds have been extensively investigated for their antidiabetic properties, with numerous clinical trials and meta-analyses supporting their efficacy in improving glycemic control. A systematic review and meta-analysis of 14 trials comprising 894 participants conducted by (Shabil *et al.,* 2023) reported that fenugreek consumption resulted in reductions in fasting blood glucose, postprandial blood glucose, and HbA1c levels, with statistically significant effects observed for HbA1c (MD: -0.88, 95% CI -1.49, -0.27; p = 0.00). Similarly, Neelakantan *et al.,* (2014) conducted a meta-analysis of 10 clinical trials and documented significant reductions in fasting blood glucose (-0.96 mmol/L), 2-hour postload glucose (-2.19 mmol/L), and HbA1c (-0.85%) in diabetic participants, with effects being dose-dependent and more pronounced in individuals with established diabetes.

The mechanistic basis for fenugreek's antidiabetic effects involves multiple pathways. The soluble fiber galactomannan delays gastric emptying and slows carbohydrate absorption, while the amino acid 4-hydroxyisoleucine stimulates insulin secretion from pancreatic β-cells (Tak *et al.,* 2024).

Additionally, fenugreek compounds enhance insulin sensitivity in peripheral tissues and exhibit protective effects on pancreatic β-cells, potentially supporting β-cell regeneration (Al Mosawi, 2021). These multifaceted mechanisms position fenugreek as a valuable complementary approach to diabetes management.

Clinical trials specifically investigating fenugreek administration in diabetic populations have demonstrated promising results. (Gaddam *et al.,* 2015) evaluated the preventive effects of fenugreek in prediabetic individuals, finding that 10 g/day for three years significantly reduced progression to type 2 diabetes, improved fasting and postprandial glucose, and enhanced serum insulin levels. Similarly, (Kassaian *et al.,* 2009) reported that administration of 10 g/day of powdered fenugreek seeds soaked in hot water to type 2 diabetic patients for eight weeks significantly reduced fasting blood glucose, triglycerides, and VLDL cholesterol. The method of administration appears to influence bioavailability and glycemic outcomes, highlighting the importance of preparation optimization.

Hypolipidemic and Cardiovascular Benefits

Fenugreek seeds demonstrate significant potential in managing dyslipidemia and supporting cardiovascular health through multiple mechanisms. The soluble fiber content binds bile acids in the intestine, increasing their fecal excretion and forcing the liver to utilize circulating cholesterol to synthesize new bile acids, thereby reducing blood cholesterol levels (Wang *et al.,* 2023). Additionally, steroidal saponins interfere with cholesterol absorption and synthesis, while flavonoids and antioxidants protect against lipid peroxidation and oxidative stress, key factors in atherosclerosis development (Hanafi *et al.,* 2022).

A systematic review and meta-analysis of randomized controlled trials investigating fenugreek's effects on blood lipids found that fenugreek supplementation significantly improved lipid parameters, including reductions in LDL cholesterol, triglycerides, and total cholesterol, along with increases in HDL cholesterol (Askarpour *et al.,* 2020). Similar findings were reported in another meta-analysis which concluded that fenugreek supplementation could be considered an effective lipid-lowering medicinal plant (Heshmat-Ghahdarijani *et al.,* 2020). These lipid-modifying effects, combined with fenugreek's antioxidant and anti-inflammatory properties, contribute to its cardioprotective potential.

Preclinical studies provide insights into the molecular mechanisms underlying fenugreek's hypolipidemic effects. (Kumar *et al.,* 2014) demonstrated that fenugreek seed extract inhibited fat accumulation and ameliorated dyslipidemia in high fat diet-induced obese rats by modulating lipogenic enzyme activity and enhancing antioxidant defenses. Similarly, (Muraki *et al.,* 2011) observed that dietary fenugreek supplementation in high-fat, high-sucrose-fed rats reduced plasma triglycerides, total cholesterol, and hepatic lipid content while improving insulin sensitivity. These findings support fenugreek's regulatory role in lipid metabolism and potential application in managing metabolic syndrome.

Antioxidant and Anti-inflammatory Activities

Fenugreek seeds contain numerous antioxidant compounds, including polyphenols, flavonoids, and vitamins C and A, which combat oxidative stress by neutralizing free radicals and reducing cellular damage (Hozzein *et al.,* 2020). The antioxidant activity of fenugreek seeds has been demonstrated in various in vitro and in vivo studies, with extracts showing capacity to scavenge reactive oxygen species, inhibit lipid peroxidation, and enhance endogenous antioxidant enzyme systems such as superoxide dismutase, catalase, and glutathione peroxidase.

The anti-inflammatory properties of fenugreek have been documented in both animal models and limited human studies. Bioactive compounds in fenugreek, including diosgenin and flavonoids, inhibit pro-inflammatory cytokine production and suppress inflammatory mediator expression through modulation of NF-κB and other signaling pathways (Gavarti *et al.,* 2025). These anti-inflammatory effects potentially benefit conditions like arthritis, respiratory inflammation, and inflammatory bowel diseases, though more human trials are needed to confirm efficacy.

Ravikumar and Anuradha (1999) demonstrated that fenugreek supplementation normalized disrupted free radical metabolism in alloxan-induced diabetic rats, increasing glutathione and β-carotene while reducing lipid peroxidation. Similarly, (Mohammad-Sadeghipour *et al.,* 2020) reported that hydro-alcoholic fenugreek extracts lowered malondialdehyde levels and increased antioxidant enzymes in fructose-fed rats. These antioxidant effects complement fenugreek's metabolic benefits, providing protection against oxidative damage associated with chronic diseases.

Food Applications and Culinary Uses

Fenugreek seeds and leaves serve diverse culinary purposes across various food traditions, particularly in South Asian, Middle Eastern, and North African cuisines.

Table.1 Historical Timeline of Fenugreek Use (Rajendram et al., 2023)

Era	Geographical Region	Primary Uses
Ancient Egypt (1500 BC)	Nile Valley	Medicinal purposes, embalming rituals
Ancient Greece & Rome	Mediterranean	Spice, fodder, therapeutic oil
Middle Ages	Europe, Arab regions	Medicinal plant, lactation aid
Modern Era	Worldwide	Functional food, nutraceutical, spice

Table.2 Proximate Composition of Yemeni and Saudi Fenugreek Seeds (Adapted from (Al-Sebaeai *et al.,* 2017c))

Analysis	Yemeni Seed (%)	Saudi Seed (%)
Moisture	8.91	10.23
Crude fat	5.69	3.54
Crude protein	14.81	15.34
Crude fiber	12.97	11.24
Ash	3.53	3.26
Total carbohydrate	54.09	56.39

Table.3 Vitamin and Mineral Composition of Fenugreek Seeds

Vitamin	Content (per 100g)	Mineral	Content (per 100g)
Vitamin A	1040 IU	Calcium	176 mg
Vitamin C	12 mg	Iron	33.5 mg
Niacin	6 mg	Zinc	2.5 mg
Pyridoxine (B6)	0.6 mg	Phosphorus	296 mg
Thiamine (B1)	0.41 mg	Magnesium	191 mg
Riboflavin (B2)	0.36 mg	Manganese	1.22 mg
Nicotinic acid	1.1 mg	Selenium	6.3 µg
Folate	57g		

Table.4 Food Applications of Fenugreek Seeds and Derivatives

Application Area	Specific Uses	Functional Role	References
Bakery Products	Bread, biscuits, cakes	Dough conditioner, emulsifier, fiber enrichment	(Stampfli & Nersten, 1995)
Dairy Products	Cheese, ice cream	Stabilizer, flavoring agent	(Lal *et al.,* 2006)
Meat Products	Sausages, processed meats	Binder, water retention, fat replacer	
Beverages	Functional drinks, teas	Thickening agent, bioactive component delivery	(Rastegarpour *et al.,* 2025)
Condiments & Spice Blends	Curries, pickles, chutneys	Flavoring, aroma enhancement	(Lamkey, 2022)

The seeds possess a distinctive bitter taste and strong aroma, which mellow upon heating, releasing a complex flavor profile described as sweet, nutty, and reminiscent of maple syrup or caramel (Mandal & DebMandal, 2016; Żuk-Gołaszewska & Wierzbowska, 2017). This unique sensory characteristic has led to fenugreek's

incorporation as a flavoring agent in foods, beverages, and even artificial maple syrup formulations (Faisal *et al.,* 2024a)

In traditional food preparation, fenugreek seeds are typically dry-roasted or soaked to reduce bitterness before being ground into spices or incorporated whole into dishes. They constitute an essential component of various spice blends, including Indian curries, pickles, and chutneys, as well as Ethiopian berbere and Yemeni zhug. Young fenugreek leaves and sprouts are consumed as vegetables, providing a slightly bitter, aromatic addition to salads, cheeses, and flatbreads (Sarkar *et al.,* 2015).

The functional properties of fenugreek seeds, particularly their high fiber and gum content, have enabled various industrial food applications. Fenugreek gum, rich in galactomannans, serves as a valuable additive for stabilizing and providing dietary fiber in numerous food products (Ağagündüz *et al.,* 2022). This versatile gum functions as a stabilizer, emulsifier, and hydrocolloid, effectively modifying water behavior—a common component in diverse foods. In baking applications, incorporating fenugreek gum into biscuits or cake dough enhances workability, facilitating easy release from molds and clean slicing post-baking (Banyal *et al.,* 2022; Faisal *et al.,* 2024b).

Fenugreek gum demonstrates excellent water retention capabilities in both hot and cold environments, making it a valuable lubricant, stabilizer, and binder in prepared meat products like hotdogs, stuffed meats, and sausages (Frangopoulos, 2022). Hydrocolloids like fenugreek gum offer various functional benefits, including controlling syneresis and preventing fat migration during the storage of meat and meat products (Eghbaljoo *et al.,* 2022). In the beverage industry, fenugreek gum serves as an effective tool for viscosity control and thickening, owing to its inherent properties and resistance to degradation even in low pH conditions commonly found in beverages (Singh *et al.,* 2022).

Beyond traditional culinary applications, fenugreek seeds are increasingly utilized in the development of functional foods and nutraceuticals targeting metabolic health. Their high fiber and protein content, combined with documented bioactivity, position fenugreek as an ideal ingredient for formulating foods designed to manage diabetes, support weight control, and promote cardiovascular health. Innovative applications include fenugreek-enriched baked goods, extruded snacks, and ready-to-drink beverages that deliver therapeutic benefits while maintaining acceptable sensory properties.

Adverse Effects of Fenugreek

The increasing global reliance on herbal remedies, including dietary supplements and traditional medicinal plants, has highlighted concerns regarding their safety profile. Although approximately 80% of the world's population utilizes herbal products for preventive, therapeutic, or palliative purposes (Haber & Keonavong, 2013a; Joseph *et al.,* 2018), these substances are often exempt from rigorous regulatory oversight, creating potential risks for adverse effects (Boullata & Nace, 2000). Fenugreek (*Trigonella foenum-graecum* L.), widely employed as a culinary spice and traditional therapeutic agent, has been associated with both minor and clinically significant adverse reactions. While previous studies have primarily focused on its pharmacological efficacy and general toxicity, there is limited synthesis specifically addressing reported adverse effects.

Documented adverse effects of fenugreek encompass allergic and hypersensitivity reactions, including angioedema, anaphylaxis, Stevens-Johnson syndrome, and toxic epidermal necrolysis (Joseph *et al.,* 2018; Patil *et al.,* 1997). Less frequent but notable effects include serotonin syndrome, elevated international normalized ratio (INR), dizziness, syncope, and a characteristic maple syrup odor in infants following maternal consumption (Doolabh *et al.,* 2019; Korman *et al.,* 2001; Lambert & Cormier, 2001a). Gastrointestinal disturbances, such as mild indigestion, bloating, and abdominal discomfort, represent the most commonly reported effects, typically resolving without medical intervention (Boullata & Nace, 2000). All adverse events reported in clinical and observational studies were reversible, with most cases not requiring therapeutic management.

The mechanisms underlying these adverse effects are multifactorial. Gastrointestinal symptoms are attributed to fenugreek's high dietary fiber content, which may also alter absorption of concomitant oral medications (Rao & Grant, 2020). Its hypoglycemic action, mediated through enhanced insulin signaling and inhibition of carbohydrate absorption, poses a risk of hypoglycemia, particularly in diabetic patients (Haber & Keonavong, 2013b; Sharma, 1986). Fenugreek intake can lower

serum potassium levels, which, in combination with diuretics or other hypokalemic agents, may precipitate hypokalemia and increase susceptibility to cardiac glycoside toxicity (Patil *et al.,* 1997; Rao & Grant, 2020). Neurological manifestations, including dizziness or syncope, are likely related to hypoglycemia or reductions in systolic blood pressure (Haber & Keonavong, 2013b). Fenugreek seed extracts have also shown central nervous system stimulant and depressant effects, suggesting potential seizure provocation in epileptic individuals (Bentele-Jaberg *et al.,* 2015).

Allergic reactions remain the most clinically significant complication, particularly in individuals with known sensitivities to Fabaceae family members such as peanuts, peas, or coriander (Aurich *et al.,* 2019; Ebo *et al.,* 2006). Furthermore, interactions with serotonergic drugs, such as selective serotonin reuptake inhibitors, may elevate the risk of serotonin syndrome (Doolabh *et al.,* 2019), and concomitant use with anticoagulants such as warfarin may increase INR (Lambert & Cormier, 2001b). Although a rare benign effect includes a maple syrup odor in infant urine or sweat following maternal intake (Korman *et al.,* 2001), the long-term safety profile of fenugreek remains incompletely characterized due to limited longitudinal studies. Collectively, these findings emphasize the necessity of cautious use of fenugreek, particularly among vulnerable populations, and the importance of further systematic evaluation of its safety.

In conclusion, Yemeni fenugreek (*Trigonella foenum-graecum* L.) is a nutritionally rich and bioactive herb with significant therapeutic potential, particularly in managing diabetes, dyslipidemia, and oxidative stress. Its seeds provide essential macronutrients, vitamins, minerals, and unique compounds such as diosgenin, 4-hydroxyisoleucine, and trigonelline, which contribute to its health-promoting effects.

Beyond medicinal applications, fenugreek demonstrates versatile functional food uses, enhancing dietary fiber, texture, and bioactive content in various food products. While generally safe, documented adverse effects including allergic reactions, gastrointestinal disturbances, and potential drug interactions highlight the need for cautious consumption and further safety evaluation. Overall, Yemeni fenugreek represents a valuable resource for nutraceutical development and functional food innovation, warranting continued research to fully exploit its nutritional and therapeutic properties.

Limitations

The current research on Yemeni fenugreek faces several limitations. First, there is a scarcity of comprehensive clinical trials specifically evaluating this regional variety, limiting the generalizability of findings. Second, variations in cultivation practices, soil composition, and climate introduce inconsistencies in bioactive compound concentrations, complicating standardization. Third, most existing studies focus on short-term effects, with limited data on long-term safety and efficacy. Fourth, adverse effect reporting is inconsistent, particularly regarding interactions with medications and vulnerable populations. Finally, comparative analyses with other regional fenugreek varieties remain limited, restricting a full understanding of its unique biochemical and functional properties.

Author Contributions

Tariq Al-Samai: Investigation, formal analysis, writing—original draft. Mohammed Alsebaeai: Validation, methodology, writing—reviewing. Mohammed- Al-qarwani:—Formal analysis, writing—review and editing. Mansour Ghaleb: Investigation, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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