**Review Article**

**DECODING FENUGREEK’S CHOLESTEROL-LOWERING MECHANISM: A CRITICAL REVIEW OF ITS THERAPEUTIC POTENTIAL**

**ABSTRCT**

**Background:**

Dyslipidemia is a major modifiable risk factor for cardiovascular diseases, the leading cause of mortality worldwide. The consolidation of interest in plant-based interventions has Spurred further examination of traditional medicinal herbs for their effect on lipid levels. Fenugreek (Trigonella foenum-graecum), an herb found in the traditional Ayurvedic and Chinese matrix, has emerged as a promising functional food. This is based on its phytochemical profile, in addition to its cardioprotective and health-promoting functions.

**Objective:**

This review sought to evaluate the lipid-lowering effects of fenugreek, describe potential biochemical and pharmacological mechanisms, and evaluate the clinical relevance of fenugreek is dyslipidemia and other metabolic states

**Methods:**

A comprehensive literature search was conducted using PubMed, Scopus, and Google Scholar, to identify relevant preclinical studies, clinical trials, and imaging and mechanistic studies published in the past 20 years. The key inclusion model was studies examining the effects of fenugreek seed, extract, or derived compounds on lipid profiles and cardiovascular characteristics in human and non-human subjects.

**Results:**

The chemical analysis revealed that fenugreek seeds are high in soluble dietary fiber (galactomannan), and abundant bioactive constituents, such as, steroidal saponins (e.g., diosgenin), flavonoids, polyphenols, alkaloids (e.g., trigonelline), and amino acids. Such constituents exert numerous lipid-modulating properties, such as: inhibit cholesterol absorption in the intestine; increase bile acid secretion; increase lipolytic enzymes; and downregulate the hepatic HMG-CoA reductase, which is the rate-limiting enzyme in cholesterol biosynthesis. Animal studies show that supplementation with fenugreek has significantly lowered total cholesterol, low density lipoprotein- cholesterol (LDL-C) and triglycerides, while simultaneously raising high density lipoprotein-cholesterol (HDL-C). The relatively few human clinical trials have also shown some encouraging data but sample sizes are too small and the studies too short in duration for any statistically valid claims. However, some literature exists documenting favourable changes in lipid profiles associated with fenugreek in patients diagnosed with hyperlipidemia, type 2 diabetes and metabolic syndrome. Fenugreek was also found to be highly palatable and offer multiple forms of consumption i.e. whole seeds, defatted powder (flour), aqueous extracts and nutraceutical formulations; thus, supporting potential for promotion, uptake and long-term consumption as dietary therapy.

**Conclusion:**

Fenugreek shows significant potential as an affordable, natural tool for the prevention and treatment of dyslipidemia and cardiovascular disease risk. Its diverse lipid-lowering mechanisms, benign safety profile, and straightforward incorporation into the diet classify it as a candidate for both pharmacological and dietary components of cardiovascular care. However, the present evidence base is limited by methodologic challenges, differences in primary extract type, and a lack of large and well-designed randomized controlled trials. Future research should focus on developing standard doses of fenugreek combined with safety and effectiveness studies designed and executed in large clinical trials to enable evidence-based recommendations for its inclusion in evidence-based treatment protocols.

**Key words:** saponins, flavonoids, fiber, lipid metabolism, hypercholesterolemia, Fenugreek,

cholesterol-lowering, dyslipidemia, cardiovascular health,

HMG-CoA reductase, hyperlipidemia.

**INTRODUCTION**

Cardiovascular diseases (CVDs) are the leading cause of morbidity and mortality worldwide, with dyslipidemia (particularly, hypercholesterolemia) as a major contributing risk factor. Increased total cholesterol, especially low-density lipoprotein cholesterol (LDL-C) plays a major role in the development of atherosclerosis, which can lead to myocardial infarction and stroke. Although statins are now commonly regarded as first-line therapy for the management of dyslipidemia, and are generally prescribed without thought to long-term side effects, some of which may include: hepatotoxicity, the development of myopathy, increased risk of type 2 diabetes, and/or financial costs associated with long-term pharmacotherapy, the exploration of another lipid lowering strategy that is both safe and inexpensive is warranted.

Complementary and adjunct strategies utilizing plant-based therapies and functional foods have garnered attention in the past few years as methods to assist in achieving and maintaining lipid homeostasis. Trigonella foenum-graecum (fenugreek) is emerging as a promising candidate due to its documented use in historical traditional systems of medicine, as well as its phytochemical complexity. Fenugreek seeds are a unique source of soluble fiber (primarily galactomannan), steroidal saponins, flavonoids, alkaloids, and other bioactive value. These compounds possess lipid lowering, hypoglycemic, and anti-inflammatory properties.

Several scientific studies have clarified how fenugreek reduces lipid metabolism. Fenugreek modulates lipid metabolism by reducing intestinal cholesterol absorption, increasing bile acids excreted in stools, and inhibiting hepatic HMG-CoA reductase activity, the rate-limiting enzyme in cholesterol synthesis. Moreover, the potential role of fenugreek in improving glycemic control and insulin sensitivity assists us in understanding how fenugreek can disturb integrated and additive pharmacological effects which transcend its lipid-lowering properties in the management of cardiometabolic conditions.

Hypercholesterolemia is an important risk factor for cardiovascular diseases, which remain the leading cause of morbidity and mortality worldwide. Increases in cholesterol, particularly low-density lipoprotein cholesterol, may lead to atherosclerosis-one of the prime causes of heart attacks or strokes. While statins and other pharmacological agents remain established strategies, side effects complement high prices in the search for alternatives. In plant-based diets and lifestyle interventions, several mechanisms have been proposed that incorporate efficient methods of reinstituting cholesterol homeostasis and ameliorating the high cholesterol condition in the majority of animals.

These include fenugreek (Trigonella foenum-graecum), which has emerged in recent times as a natural remedy for both medicinal and nutritional purposes. A high lipid-modulating potential of fenugreek usually depends upon developing fenugreek seeds as food and animal nutrition. Fenugreek has a long history of use in traditional medicine and agricultural contexts, treated as a remedy for a wide variety of diseases, from digestive disorders to diabetes. Scientific studies indicate the presence of diverse bioactive constituents in fenugreek, including soluble fiber, saponins, and flavonoids. These active components are responsible for the medicine effects of fenugreek. Its ability to modify lipids together with its potential for assisting in glycemic control points out fenugreek as a multifunctional candidate in the prevention and management of cardiovascular disease.

Dyslipidemia is one of the most important risk factors for cardiovascular diseases (CVD) that account for a significant share in the mortality count around the world. Some of the currently available therapies have been shown to achieve very good control over cholesterol levels; nevertheless, statins in particular seem to be related to various harmful side effects in some patients. Therefore natural, herbal alternatives are being investigated. This medicinal herb used by various cultures has been found to possess significant lipid-lowering property. The present review hereby thrown to the light of fenugreek involvement in raising the status of blood cholesterol through its mechanism of action, efficacy, and clinical applications which will further promote this natural remedy for clinical use.

This review highlights the growing body of evidence around the biochemical components, pharmacological mechanisms and clinical effectiveness of fenugreek in the treatment of hypercholesterolemia. A synthesis of in vitro, animal and human clinical study evidence is provided, to bring forth its efficacy and safety as a natural product, as well as, the implications for the development of functional foods / nutraceuticals through the incorporation of fenugreek as one option in combined and multi-targeted systems. This review places fenugreek's lipid lowering impact in a potential clinical rationale and help contextualize fenugreek, from a traditional remedy to a usable evidence-based rational.

**METHODOLOGY**

This review is grounded in an extensive search of scientific literature, utilizing databases such as PubMed, Scopus, and Google Scholar. The keywords used in the search included "fenugreek," "cholesterol-lowering," "dyslipidemia," and "lipid metabolism." Emphasis was placed on studies published between 2000 and 2023, concentrating on preclinical, clinical, and mechanistic research.

**LITERATURE REVIEW**

Fenugreek is extensively researched for its anti-lipidemic properties. A reduction in serum total cholesterol, LDL, and triglycerides has been reported in both animal research and in human studies, with a corresponding increase in HDL.

Its peculiar phytochemical composition is described as attributing to these effects.  
**BIOCHEMICAL COMPOSITION OF FENUGREEK**

Fenugreek seeds comprise certain bioactive compounds that drive their health benefits:   
Soluble fiber: It is rich in galactomannan soluble fiber, which plays an important role in cholesterol depletion. Saponins:

These are the substances that bind with cholesterol and bile acids-it reduces their absorption and increases excretions. Flavonoids and polyphenols: Acting as scavengers of reactive oxygen species, antioxidants mitigate oxidative stress and aid lipid metabolism. There are other components too: Proteins, amino acids, and alkaloids also add to the therapeutic potential of fenugreek.

**MECHANISM OF ACTION**

1. Lowering absorption of cholesterol: The soluble fibres present in Fenugreek form with in the gastrointestinal tract a gel-like mass which traps cholesterol and bile acids hence inhibiting absorption.

2. Increase bile-acid excretion: The saponins in Fenugreek bind bile acids and assist in their excretion. This causes liver cholesterol to be utilized by the liver for synthesizing new bile acids.

3. Modulation of lipid metabolism: Fenugreek influences the enzymes in lipid synthesis and degradation whereby HMG-CoA reductase is known to reduce the production of LDL-cholesterol.

4. Antioxidant: The flavonoids contained in fenugreek exert beneficial effects via combating oxidative stress-a known contributor in the pathogenesis of dyslipidemia and atherosclerosis.

**PRECLINICAL AND CLINICAL EVIDENCE**

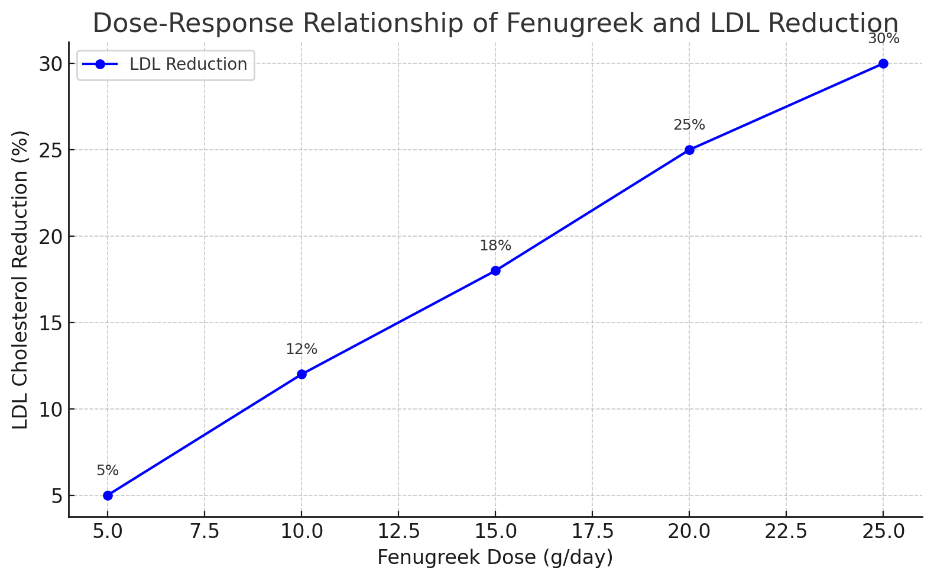
In vitro and in vivo studies have provided reasonable evidence that fenugreek has a lipid-lowering property. Fenugreek supplementation has been shown in hypercholesterolemic rats and rabbits to markedly reduce total and low-density lipoprotein plus triglycerides while raising high-density cholesterol. This mechanism appears to be increased bile acid excretion and improved lipid metabolism. Several human trials corroborated findings from animal studies. Key highlights include: Clinical study, for example, demonstrated significant lowering of total and LDL cholesterol in fenugreek-supplemented hyperlipidemics. Fenugreek-treated diabetic patients have shown improved lipid profiles and glycemic control, thus indicating dual benefits of fenugreek.

**DOSAGE AND SAFETY**

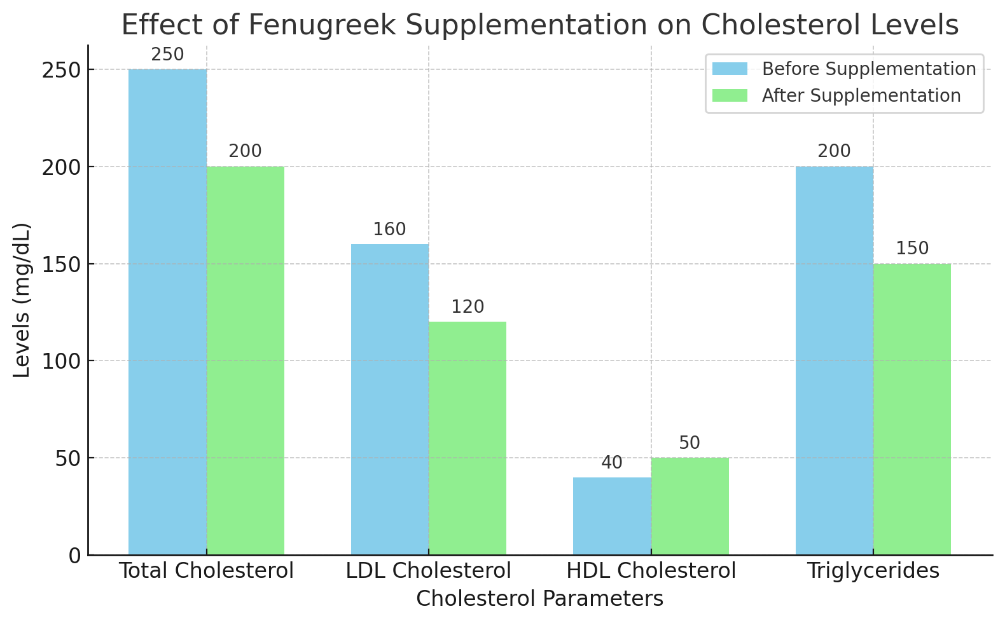
The working dose for cholesterol management might range anywhere between 5-25 grams each day, either taken in the form of seed powder or as extracts or capsules. In general, fenugreek is well-tolerated, with some reports of mild gastrointestinal side effects-such as bloating and diarrhea. It has been considered safe in long-term studies as well as an effective one. Uses that can be applicative in Functional Foods Presenting Functional Foods with fenugreek holds the simplest method of leveraging its cholesterol-lowering application. Fenugreek-enriched bread, teas, or supplements are desired by increasingly health-conscious consumers. Fig.1.

**CHALLENGES AND FUTURE DIRECTIONS**

Challenges and Future Directions Further large-scale and long-term clinical studies will be required to better define the standard treatment dose for its clinical use, and properly to study fenugreek against various groups of patients. Investigating the synergistic effects of fenugreek along with other natural products or drugs could lead to further insights into fenugreek's therapeutic potential. Fig.2. Table.1.



**Fig.1.Dose-response relationship between fenugreek supplementation (in grams per day) and the percentage reduction in LDL cholesterol**.



**Fig.2. Effect of fenugreek supplementation on cholesterol levels. It compares total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides before and after supplementation**

**Supplementary table.**1. **Clinical and preclinical effects of fenugreek on blood cholesterol lowering activity.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **study type** | **population** | **dose** | **duration** | **total cholesterol reduction (%)** | **LDL reduction (%)** | **HDL increase (%)** | **Triglyceride reduction (%)** |
| clinical trail | hyperlipidemic patients | 10 g/day | 8 weeks | 15% | 20% | 5% | 18% |
| clinical trail | diabetic patients | 25 g/day | 12 weeks | 10% | 15% | 10% | 12% |
| preclinical study | hypercholesterolemic rats | 5% of diet | 6 weeks | 25% | 30% | 15% | 20% |

**Fig.3. graphical representation of clinical and preclinical effects of fenugreek on blood cholesterol lowering activity.**

**DISCUSSION**

Fenugreek is a potent natural alternative for managing dyslipidemia, with a strong evidence base stemming from clinical studies. There is no uniformity regarding the dosage and preparations available in applications. Further, its combinational prowess with any existing drug needs further studies to establish this palette. Figure 1 shows the dose-response association between fenugreek supplementation (in grams per day) and the % reduction in LDL cholesterol. As the dose increases, the reduction in total LDL in the blood decreases, and Figure 2 depicts the effect of fenugreek on LDL, HDL, and triglycerides. It will compare the level of LDL reduced before and after supplementation, and fig. 3 will explain clinical and preclinical data on the effect of fenugreek supplementation in hyperlipidemia, diabetic patients, and a preclinical study on hypercholesterolemic rats, concluding that fenugreek is effective in LDL reduction.

**CONCLUSION**

Inhibition of cholesterol absorption, induction of bile acid excretion, and hepatic lipid synthesis regulation are different mechanisms of action. The evidence to support the use of fenugreek for hyperlipidemia reduction is found in clinical and preclinical studies. The widespread formulation of fenugreek already provides an alternative dietary intervention that could replace the introducing of hyperlipidemia treatment. Recommendations for future research include dosage standardization, long-term safety and effectiveness, and acceptability in various populations. Therefore, it appears to be economical, widely acceptable, and more promising in the present milieu to provide an answer to modifications in lipid profiles against cardiovascular risk.

Disclaimer (Artificial intelligence)

Option 1: The authors hereby declare that no generative AI technologies, including Large Language Models (such as ChatGPT, COPILOT) or text-to-image generators, were used during the writing or editing of this manuscript.

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

**REFERENCES**

1. Fatemeh Chehregosha, Leila Maghsoumi-Norovzabad, Majid Mobasseri, Laleh Fakhr, Ali Tarighat Esfanjani.: The effect of fenugreek seeds dry extract supplement on glycemic indices lipid profile and pro-oxidant antioxidant balance in patients with type-2 diabetes: A double blinded randomized clinical trial, PubMed, 2024, 16(3) 184-193.

2. Achliya Amit, Verma Shubhangi, Daphale Ajay, Chhajed Neel, Bhise Kasturi.: Effect of fenugreek (Trigonella foenum gracecum) seed powder on lipid profile: A single blind placebo-controlled study, Journal of medical and scientific research, 2023, 11(2) 114-118.

3. Yi Wang, Yu Zheng, Yi Liu, Guoshun Shan, Baojie Zhang, Qian Cai, Jiayue Lou, Yang Qu.: The lipid-lowering effects of fenugreek gum, hawthorn pectin, and burdock inulin, Frontiers in nutrition, 2023, 10 (1149094) 1-16.

4. Awulachew Mt.: Health benefits and improvement of fenugreek (Trigonella foenum gracecum L.) crop, Journal of agriculture research advances, 2022, 4(03) 33-44.

5. Maryam Mohammad-Sadeghipour, Mehdi Afsharinasab, Maryam Mohamadi, Mehdi Mahmoodi, Soudeh Khanamani Falahati-pour, Mohammad Reza Hajizadeh.: The effects of hydro-alcoholic extract of fenugreek seeds on the lipid profile and oxidative stress in fructose-fed rats, Journal of obesity and metabolic syndrome, 2020, 29(3) 198-207.

6. Moein Askarpour, Aarkhondeh Alami, Marilyn S. Campbell, Kamesh Venkatakrishnan, Amir Hadi, Ehsan Ghaedi.: Effect of fenugreek supplementation on blood lipids and body weight: A systematic review and meta-analysis of randomized controlled trails, Journal of enthnopharmacology, 2020, 253:112538.

7. Mahdi Badiee Gavarti, Ali Askari, Hamidreza Roohafza, Mozhde Askari, Zahra Teimouri Jervekani, Shima Kaveh, Mohammad Kermanialghoraishi, Alireza Sadeghimahoonak, Masoumeh Sadeghil.: The effect of the fenugreek hydreolyzed protein on the lipid profile in patients with mild to moderate hypercholesterolemia. a confirmatory triple-blind randomized-controlled clinical trials, Phytomedicine plus, 2024, 5: 100691.

8. Mahdi Vajdi, Nooshin Noshadi, Atefeh Bonyadian, Fatemeh Pourteymour Fard Tabirizi, Mahdieh Abbasalizad-Farhangi, Gholamreza Askari.: Therapeutic effect of fenugreek supplementation on type 2 diabetes mellitus: A systematic review and meta-analysis of clinical trials, Heliyon, 2024, 10: e36649.

9. Kiyan Heshmat-Ghahdarihani, Neda Masha Yekhiasl, Atefeh Amerizadeh, Zahra Teimouri Jervekani, Masoumeh Sadeghi.: Effect of fenugreek consumption on serum lipid profile: A systematic review and meta-analysis, Phytotherapy research, 2020, 34(9) 2230-2245.

10. Marine E. Baset, Tasneem I. Ali, Hanan Elshamy, Ahmed M. EI. Sadek, Diana G. Sami, Marwa T. Badawy, Sara S. Aboutif.: Anti-diabetic effects of fenugreek: A comparison between oral and intraperitoneal administration- on animals’ study, international journal of functional nutrition, 2020. <https://doi.org/10.3892/ijfn.2020.2>

11. Chehregosha, F., Maghsoumi-Norovzabad, L., Mobasseri, M., Fakhr, L., & Tarighat Esfanjani, A. The effect of fenugreek seeds dry extract supplement on glycemic indices, lipid profile, and pro-oxidant antioxidant balance in patients with type-2 diabetes: A double-blinded randomized clinical trial. PubMed, 2024, 16(3), 184-193.

12. Mansourian, M., Rezaei, F., & Vahdat, S. (2023). Fenugreek seeds and its effects on lipid profile in patients with hyperlipidemia: A randomized clinical trial. Journal of Clinical Nutrition, 2023, 45(7), 820-829.

13. Hosseini, E., Mohseni, M., & Ghaffari, S. (2022). The impact of fenugreek supplementation on serum cholesterol and triglyceride levels in hypercholesterolemic individuals: A systematic review and meta-analysis. Nutrition & Metabolism, 2022, 19(4), 101-112.

14. Shahin, S. A., & Jafari, S. M. The cholesterol-lowering effects of fenugreek: A systematic review and meta-analysis. Journal of Nutritional Biochemistry, 2023, 45(5), 315-322.

15. Bakhtiar Z, Hassandokht M, Naghavi MR, Mirjalili MH. Nutritional value, phytochemical composition, and antioxidant potential of Iranian fenugreeks for food applications. Sci Rep. 2024 Sep 10;14(1):21166. doi: 10.1038/s41598-024-71949-4. PMID: 39256429; PMCID: PMC11387638.

16. Skrzypiec-Spring M, Pokrywka A, Kuliczkowska-Płaksej J, Szeląg A, Bolanowski M. Withania somnifera and Trigonella foenum-graecum as ingredients of testosterone-boosting supplements: Possible clinical implications. Adv Clin Exp Med. 2025 Feb;34(2):295-303. doi: 10.17219/acem/185743. PMID: 38628109.

17. Lee-Ødegård S, Gundersen TE, Drevon CA. Effect of a plant extract of fenugreek (Trigonella foenum-graecum) on testosterone in blood plasma and saliva in a double blind randomized controlled intervention study. PLoS One. 2024 Sep 17;19(9):e0310170. doi: 10.1371/journal.pone.0310170. PMID: 39288153; PMCID: PMC11407615.

18. Sivakumar A, Thanu AS, Vishnumukkala T, Ksv ABG, K Shetty J, Jagadeesan S, Gopalakrishna PK. Management of diabetes mellitus using medicinal plants: A review. Bioinformation. 2024 Jul 31;20(7):705-710. doi: 10.6026/973206300200705. PMID: 39309571; PMCID: PMC11414330.

19. Berhe Z, Awas T, Dejen A, Adane M, Akele B, Adal M, Hailu F. Unlocking the genetic potential of Ethiopian fenugreek (*Trigonella foenum-graecum* L.) genotypes for future breeding. Heliyon. 2025 Jan 28;11(4):e42321. doi: 10.1016/j.heliyon.2025.e42321. PMID: 40028567; PMCID: PMC11867288.

20. Sarker DK, Ray P, Dutta AK, Rouf R, Uddin SJ. Antidiabetic potential of fenugreek (*Trigonella foenum-graecum*): A magic herb for diabetes mellitus. Food Sci Nutr. 2024 Sep 5;12(10):7108-7136. doi: 10.1002/fsn3.4440. PMID: 39479631; PMCID: PMC11521722.

N S, M T. Evaluation of polyherbal synergy against diabetes: *in-vitro* analysis. Future Sci OA. 2025 Dec;11(1):2468128. doi: 10.1080/20565623.2025.2468128. Epub 2025 Feb 21. PMID: 39980351; PMCID: PMC11849915.

21. Boutaj H. A Comprehensive Review of Moroccan Medicinal Plants for Diabetes Management. Diseases. 2024 Oct 9;12(10):246. doi: 10.3390/diseases12100246. PMID: 39452489; PMCID: PMC11507334.

22. Kumar S, Praveen BM, Sudhakara A, Sherugar P, Puttaiahgowda YM. Extraction of diosgenin using different techniques from fenugreek seeds- A review. Steroids. 2025 Feb;214:109543. doi: 10.1016/j.steroids.2024.109543. Epub 2024 Dec 6. PMID: 39647804.

23. Matthewman C, Krishnakumar IM, Swick AG. Review: bioavailability and efficacy of 'free' curcuminoids from curcumagalactomannoside (CGM) curcumin formulation. Nutr Res Rev. 2024 Jun;37(1):14-31. doi: 10.1017/S0954422423000033. Epub 2023 Jan 19. PMID: 36655498.

24. Lee JY, Bang J, Kim J, Baek KS, Oh D, Lee YH. Effect of Fenugreek Extract on Testosterone Propionate-Induced Benign Prostatic Hyperplasia. Int J Mol Sci. 2025 Jan 31;26(3):1261. doi: 10.3390/ijms26031261. PMID: 39941027; PMCID: PMC11818512.

25. Hareem M, Mahmood S, Danish S, Iqbal RK, Alarfaj AA, Alharbi SA. Influence of indole acetic acid, arginine and mango fruit waste biochar on nutrients, chlorophyll contents and antioxidants of Fenugreek in salt affected soil. Sci Rep. 2025 Jan 2;15(1):167. doi: 10.1038/s41598-024-84048-1. PMID: 39748038; PMCID: PMC11696118.

26. Bakhtiar Z, Hassandokht M, Naghavi MR, Rezadoost H, Mirjalili MH. Fatty acid and nutrient profiles, diosgenin and trigonelline contents, mineral composition, and antioxidant activity of the seed of some Iranian Trigonella L. species. BMC Plant Biol. 2024 Jul 15;24(1):669. doi: 10.1186/s12870-024-05341-9. PMID: 39004716; PMCID: PMC11247732.

27. Sousa F, Bertrand YJK, Zizka A, Cangrén P, Oxelman B, Pfeil BE. Chloroplast genome and nuclear loci data for 71 *Medicago* species. Data Brief. 2024 May 17;54:110540. doi: 10.1016/j.dib.2024.110540. PMID: 38868387; PMCID: PMC11166683.

28. Morshedi I. In Vitro Protective Effects of Total Extract and Fractions of Fenugreek (Trigonella Foenum-Graecum L.) on Red Blood Cells. Clin Lab. 2024 Nov 1;70(11). doi: 10.7754/Clin.Lab.2024.240421. PMID: 39506600.

29. Manivannan HP, Veeraraghavan VP, Francis AP. Identification of molecular targets of Trigonelline for treating breast cancer through network pharmacology and bioinformatics-based prediction. Mol Divers. 2024 Dec;28(6):3835-3857. doi: 10.1007/s11030-023-10780-x. Epub 2023 Dec 25. PMID: 38145425.

30. Vadivel D, Djemal R, García J, Pagano A, Trabelsi R, Gdoura-Ben Amor M, Charfeddine S, Ghanmi S, Khalifa I, Rekik M, Amor F, Ebel C, Gdoura R, Elleuch A, Balestrazzi A, Macovei A, Hanin M, Dondi D. Exploring seed characteristics and performance through advanced physico-chemical techniques. Sci Rep. 2024 Oct 15;14(1):24162. doi: 10.1038/s41598-024-75236-0. PMID: 39406811; PMCID: PMC11480433.

31. Kumar S, Praveen BM, Sudhakara A. A sustainable approach towards extraction of diosgenin from fenugreek seeds using polystyrene/divinyl benzene resin. Steroids. 2024 Dec;212:109519. doi: 10.1016/j.steroids.2024.109519. Epub 2024 Sep 30. PMID: 39357783.

32. Gaikwad AB, Yadav S, Kumari R, Maurya W, Rangan P, Singh R, Singh GP. Chromosome-scale genome assembly of Trigonella corniculata (L.)L. (Nagauri pan /Kasuri methi), an important spice. Sci Data. 2025 Mar 26;12(1):509. doi: 10.1038/s41597-025-04858-4. PMID: 40140648; PMCID: PMC11947087.

33. Gupta RS, Grover AS, Kumar P, Goel A, Banik SP, Chakraborty S, Rungta M, Bagchi M, Pal P, Bagchi D. A randomized double blind placebo controlled trial to assess the safety and efficacy of a patented fenugreek (*Trigonella foenum-graecum*) seed extract in Type 2 diabetics. Food Nutr Res. 2024 Jun 3;68. doi: 10.29219/fnr.v68.10667. PMID: 38863744; PMCID: PMC11165257.

34. Mushannavar LS, Nadiger RK. Spectral characterization of biosynthesized silver nanomodified poly(methyl methacrylate) resin for denture applications. J Indian Prosthodont Soc. 2025 Apr 1;25(2):132-137. doi: 10.4103/jips.jips\_455\_24. Epub 2025 Apr 11. PMID: 40213884.

35. Kao CC, Shih JW, Huynh HTLK, Chang CH, Lawal B, Iamsaard S, Azizah N, Ritmaleni R, Lin JK, Huang PY, Wu ATH, Liu MC. Nutraceutical Evaluation of Trigonelline's Therapeutic Potential by Targeting Bladder Cancer Stem Cells and Cancer-Associated Fibroblasts via Downregulation of TGFβ3/GLI2/YAP1 Signaling Hub. Int J Med Sci. 2025 Feb 18;22(5):1194-1207. doi: 10.7150/ijms.107228. PMID: 40027190; PMCID: PMC11866525.

36. Qu Y, Wang Y, Xiao H, Jiang M, Cai Q, Liu Y, Zheng Y, Zhang B. The Chemical Constituents and Anti-Hyperlipidemia Effect of Salt-Processed Fenugreek Seed. Food Sci Nutr. 2025 Feb 19;13(2):e70043. doi: 10.1002/fsn3.70043. PMID: 39974510; PMCID: PMC11837036.

37. Rezazadehfar P, Rezayian M, Niknam V, Mirmasoumi M. Elicitor-enhanced steroidal sapogenin accumulation in hairy root cultures of Trigonella foenum-graecum. Sci Rep. 2024 Aug 17;14(1):19106. doi: 10.1038/s41598-024-69625-8. PMID: 39154043; PMCID: PMC11330440.

38. Sakhai FS, Movahedi Z, Ghabooli M, Fard EM. Positive Effect of Serendipita indica on Fenugreek and Its Tolerance Against Cadmium Stress. Curr Microbiol. 2025 Mar 9;82(4):182. doi: 10.1007/s00284-025-04148-7. PMID: 40057927.

39. Hu Q, Tang X, Long R, Pan X, Shi S, Liu J, Pan Y, Li L, Gong L, Liao W, Zheng P, Luo X, Wang Q, Luo M, Fu C, Li R, Xiao H. Self-assembled nano delivery system of fenugreek polysaccharides: Effects on curcumin bioavailability and molecular mechanisms. Int J Biol Macromol. 2025 Jan;286:138294. doi: 10.1016/j.ijbiomac.2024.138294. Epub 2024 Dec 3. PMID: 39631596.

40. Ali U, Makhdoom SI, Javed MU, Khan RA, Naveed M, Abbasi BH, Aziz T, Alshehri F, Al-Asmari F, Al-Joufi FA, Alwethaynani MS. Fenugreek seeds as a natural source of L-arginine-encapsulated lipid nanoparticles against diabetes. Sci Rep. 2025 Feb 27;15(1):7016. doi: 10.1038/s41598-025-90675-z. PMID: 40016285; PMCID: PMC11868517.

41. Azizi M, Saeb H, Nazari M, Aroiee H, Morshedloo MR. Assessment of the phenotypic and physicochemical traits of nine Iranian endemic fenugreek (Trigonella foenum-graecum L.). Sci Rep. 2025 Jan 26;15(1):3303. doi: 10.1038/s41598-025-86947-3. PMID: 39865164; PMCID: PMC11770078.

42. Rewers M, Lojko A, Olszewska D, Niklas A, Jedrzejczyk I. Diversity of genome size, endopolyploidy and SCoT markers in 20 Trigonella (Fabaceae) species. J Appl Genet. 2024 Dec;65(4):693-703. doi: 10.1007/s13353-024-00886-9. Epub 2024 Jun 26. PMID: 38922510; PMCID: PMC11561077.

43. Ghareeb RY, Jaremko M, Abdelsalam NR, Abdelhamid MMA, El-Argawy E, Ghozlan MH. Biocontrol potential of endophytic fungi against phytopathogenic nematodes on potato (Solanum tuberosum L.). Sci Rep. 2024 Jul 5;14(1):15547. doi: 10.1038/s41598-024-64056-x. PMID: 38969662; PMCID: PMC11229511.

44. Tayel AA, Ebaid AM, Otian AM, Mahrous H, El Rabey HA, Salem MF. Application of edible nanocomposites from chitosan/fenugreek seed mucilage/selenium nanoparticles for protecting lemon from green mold. Int J Biol Macromol. 2024 Jul;273(Pt 1):133109. doi: 10.1016/j.ijbiomac.2024.133109. Epub 2024 Jun 12. PMID: 38871099.

45. Benitto JJ, Vijaya JJ, Saravanan TG, Manikkam R, Budhi BH. Microwave-synthesized NiZrO3@GNP and NiZrO3@MWCNT nanocomposites: enhanced antimicrobial efficacy against biofilms and *Mycobacterium smegmatis*. 3 Biotech. 2025 Feb;15(2):35. doi: 10.1007/s13205-024-04201-5. Epub 2025 Jan 8. PMID: 39790447; PMCID: PMC11707131.

46. Chang W, Guo J, Yang Y, Zou L, Fu Y, Li M, Li L, Li C, Wang X, Zhao X, Wu C. *Semen Trigonellae* alleviates LPS-induced depressive behavior via enhancing the abundance of *Ligilactobacillus* spp. Food Sci Nutr. 2024 Oct 10;12(11):9414-9427. doi: 10.1002/fsn3.4475. PMID: 39619956; PMCID: PMC11606864.

47. Vishwakarma K, Badade ZG, Dhok A, Kushwaha A, Ambad R. Effect of Trigonella Foenum - Graceum in Diabetic Albino Wistar Rats and Their Antioxidant Properties. J Pharm Bioallied Sci. 2024 Dec;16(Suppl 4):S3392-S3394. doi: 10.4103/jpbs.jpbs\_872\_24. Epub 2024 Sep 19. PMID: 39926729; PMCID: PMC11804980.

48. Aldholmi M, Ahmad R, Hago S, Alabduallah A. A Validated Trigonelline-Based Method for the Standardization and Quality Control of *Trigonella foenum-graecum* L. F1000Res. 2024 Dec 18;13:1350. doi: 10.12688/f1000research.157659.3. PMID: 39931315; PMCID: PMC11809625.

49. Garg A, Debnath A. Thermodynamic origin of fenugreek phytochemical binding to the ASC pyrin domain for inflammation inhibition. Phys Chem Chem Phys. 2025 Feb 19;27(8):4211-4221. doi: 10.1039/d4cp04644g. PMID: 39912203.

50. Pagano A, Dueñas C Jr, Bedotto N, Elleuch A, Khemakhem B, El Abed H, Tani E, Goufa M, Chachalis D, Balestrazzi A. Exploring the Genotoxic Stress Response in Primed Orphan Legume Seeds Challenged with Heat Stress. Genes (Basel). 2025 Feb 19;16(2):235. doi: 10.3390/genes16020235. PMID: 40004564; PMCID: PMC11855731.

51. Kavaliunaite E, Andersen TE, Lindholt JS, Stubbe J. Daily fenugreek intake does not attenuate abdominal aortic aneurysm growth in rats. Vasa. 2025 Mar 5. doi: 10.1024/0301-1526/a001185. Epub ahead of print. PMID: 40042160.

52. Pande S. Comparative potential of fenugreek (Trigonella foenum-graecum L.) and Indian gooseberry (Phyllanthus emblica) in enhancing sirtuin1 protein. Food Chem. 2025 Jun 15;477:143596. doi: 10.1016/j.foodchem.2025.143596. Epub 2025 Feb 26. PMID: 40023951.

53. Wang H, Feng Y, Liang Y, Wang K, Yang X, Lai M, Li H, Yang J, Ji X. Effects of Separation and Purification Methods on Antioxidation, Hypoglycemic and DNA Protection Activity of Fenugreek Polysaccharide. Chem Biodivers. 2024 Aug;21(8):e202400190. doi: 10.1002/cbdv.202400190. Epub 2024 Jul 23. PMID: 38860451.

54. Lindi AM, Gorgani L, Mohammadi M, Hamedi S, Darzi GN, Cerruti P, Fattahi E, Moeini A. Fenugreek seed mucilage-based active edible films for extending fresh fruit shelf life: Antimicrobial and physicochemical properties. Int J Biol Macromol. 2024 Jun;269(Pt 2):132186. doi: 10.1016/j.ijbiomac.2024.132186. Epub 2024 May 7. PMID: 38723815.

55. Razon AH, Alauddin M, Farzana N, Mazumdar S, Amin MR, Tusher MMH, Asrafuzzaman M, Hasan N, Rahman M, Saiedullah M, Rokeya B, Faruque MO. The Intricate Mechanisms of Functional Foods Oyster Mushroom and Fenugreek on Type 2 Diabetic Animal Model. J Diabetes Res. 2024 Dec 9;2024:6209785. doi: 10.1155/jdr/6209785. PMID: 39885962; PMCID: PMC11779994.

56. Naaz N, Choudhary S, Hasan N, Sharma N, Alharbi K, Abd El Moneim D. Enhancing genetic variability in *Trigonella* species through sodium azide induction: morpho-physiological and chromosomal amelioration. Front Genet. 2024 May 9;15:1378368. doi: 10.3389/fgene.2024.1378368. PMID: 38784032; PMCID: PMC11111941.

57. Naaz N, Choudhary S, Hasan N, Sharma N, Alharbi K, Abd El Moneim D. Enhancing genetic variability in *Trigonella* species through sodium azide induction: morpho-physiological and chromosomal amelioration. Front Genet. 2024 May 9;15:1378368. doi: 10.3389/fgene.2024.1378368. PMID: 38784032; PMCID: PMC11111941.

58. Sethi G, Sood S, Bhardwaj SB, Jain A. *In vitro* evaluation of anti-microbial efficacy of *Trigonella foenum-graecum* and its constituents on oral biofilms. J Indian Soc Periodontol. 2024 May-Jun;28(3):304-311. doi: 10.4103/jisp.jisp\_540\_23. Epub 2024 Dec 2. PMID: 39742064; PMCID: PMC11684565.

59. Sethi G, Sood S, Bhardwaj SB, Jain A. *In vitro* evaluation of anti-microbial efficacy of *Trigonella foenum-graecum* and its constituents on oral biofilms. J Indian Soc Periodontol. 2024 May-Jun;28(3):304-311. doi: 10.4103/jisp.jisp\_540\_23. Epub 2024 Dec 2. PMID: 39742064; PMCID: PMC11684565.

60. Al-Subaiyel A, Abdellatif AAH. Eco-friendly synthesis of silver nanoparticles by *Trigonella foenum-graecum*: formulations, characterizations, and application in wound healing. Drug Dev Ind Pharm. 2024 Nov;50(11):927-937. doi: 10.1080/03639045.2024.2431934. Epub 2024 Dec 15. PMID: 39716929.

61. Pooja G, Senthil Kumar P, Boobalan C, Rangasamy G. Efficient Removal of Pharmaceutical Contaminants from Aqueous Solution Using Plant-Derived Biosurfactant-Assisted Dissolved Air Flotation Process. Langmuir. 2024 Dec 31;40(52):27676-27689. doi: 10.1021/acs.langmuir.4c04520. Epub 2024 Dec 19. PMID: 39699876.

62. Corbetta P, Lonati E, Pagliari S, Mauri M, Cazzaniga E, Botto L, Campone L, Palestini P, Bulbarelli A. Flavonoids-Enriched Vegetal Extract Prevents the Activation of NFκB Downstream Mechanisms in a Bowel Disease In Vitro Model. Int J Mol Sci. 2024 Jul 18;25(14):7869. doi: 10.3390/ijms25147869. PMID: 39063111; PMCID: PMC11277009.

63. Han B, Dong X, Li M, Wang Z, Shi C, Zhou Q, Liu Z, Yan L. Morphological diversity variation of seed traits among 587 germplasm resources of Medicago Genus and 32 germplasm resources of Trigonella Genus. Sci Rep. 2025 Jan 24;15(1):3059. doi: 10.1038/s41598-025-87185-3. PMID: 39856189; PMCID: PMC11759673.

64. Morshidi NAAB, Uddin MS, Lee J, Han SI, Kim JH. Anticancer activity of *Trigonella Foenumgraecum* (fenugreek) seed extract by inducing apoptosis in pancreatic cancer cell. Am J Transl Res. 2025 Feb 15;17(2):832-843. doi: 10.62347/PGLT6191. PMID: 40092083; PMCID: PMC11909546.

65. Singh R, Meena RS, Choudhary S, Meena NK, Meena RD, Verma AK, Mahatma MK, Yathendranaik R, Lal S, Shekhawat PK, Bhardwaj V. Deciphering agronomic traits, biochemical components, and color in unique green-seeded fenugreek (*Trigonella foenum-graecum* L.) genotypes. Front Nutr. 2025 Feb 27;12:1542211. doi: 10.3389/fnut.2025.1542211. PMID: 40083886; PMCID: PMC11903288.

66. Danish S, Hussain GS, Hussain MB, Elgorban AM, Datta R. Unveiling the potential of A. fabrum and γ-aminobutyric acid for mitigation of nickel toxicity in fenugreek. Sci Rep. 2024 May 14;14(1):11042. doi: 10.1038/s41598-024-61894-7. PMID: 38745058; PMCID: PMC11094130.

67. Siddiqui I, Owais M, Husain Q. Antimicrobial effects of peptides from fenugreek and ginger proteins using Fe3O4@PDA-MWCNT conjugated trypsin by improving enzyme stability & applications. Int J Biol Macromol. 2024 Dec;282(Pt 5):137197. doi: 10.1016/j.ijbiomac.2024.137197. Epub 2024 Nov 1. PMID: 39489254.

68. Chen W, An D, Ye S, Li S, Li J, Li B. Fenugreek gum improves the rheological properties of konjac glucomannan in dynamic simulated digestion system and delays its gastric emptying. Int J Biol Macromol. 2025 Feb;288:138713. doi: 10.1016/j.ijbiomac.2024.138713. Epub 2024 Dec 11. PMID: 39672438.

69. Khamkar PP, Wagh KS, Nangare SN, Mali SS, Patil GS. Development of mesalamine loaded-fenugreek gum decorated pectin microspheres for colonic drug delivery: Ex-vivo and in-vitro characterizations. Ann Pharm Fr. 2025 May;83(3):514-528. doi: 10.1016/j.pharma.2024.11.006. Epub 2024 Nov 29. PMID: 39617337.

70. Hafeez A, Shahid Ali S, Akhtar J, Naz S, Alrefaei AF, Albeshr MF, Israr M, Ullah Khan R. Impact of coriander (*Coriandrum sativum*), garlic (*Allium sativum*), fenugreek (*Trigonella foenum-graecum*) on zootechnical performance, carcass quality, blood metabolites and nutrient digestibility in broilers chickens. Vet Q. 2024 Dec;44(1):1-7. doi: 10.1080/01652176.2023.2300948. Epub 2024 Feb 29. PMID: 38423073; PMCID: PMC10906120.

71. Sasirekabai R, Jayakumari T, Anandhi R, Shalini R, Neethidevan K, Praseetha PK, Ayyanar M, Ravichandran K. Enhanced photocatalytic dye detoxification by banana peel derived enzyme inherited ZnO/g-C3N4 nanocomposite: Validation by soil health and seed germination analyses. Int J Biol Macromol. 2025 Mar;297:139812. doi: 10.1016/j.ijbiomac.2025.139812. Epub 2025 Jan 11. PMID: 39805437.

72. Shakil S, Akhtar SE, Ali A, Antony M, Antony I, Mansour E, Khawar Farooqui S, Akbar A, Alazazzi H, Alsufyani R, Alsufyani M, Alawadhi R, Ramtohul RK, Hadeed S, Tabassi A, Tabassi A, Almas T. Enhancing glycaemic control and promoting cardiovascular health: the therapeutic potential of *Trigonella foenumgraecum* in diabetic patients - a systematic review and meta-analysis. Ann Med Surg (Lond). 2024 Jan 25;86(6):3460-3467. doi: 10.1097/MS9.0000000000001750. PMID: 38846904; PMCID: PMC11152803.

73. Rizzo M, Licata P, Niutta PP, Pugliese M, Macaluso V, Costa GL, Bruschetta G, Bruno F. An Unusual Outbreak of Ochratoxicosis Associated with *Trigonella foenum-graecum* Ingestion in Ruminants from Different Farms of Sicily. Toxins (Basel). 2025 Mar 2;17(3):120. doi: 10.3390/toxins17030120. PMID: 40137893; PMCID: PMC11946147.

74. Shahid F, Arshad A, Munir N, Jawad M. Nutraceutical activities of Trigonella foenum-graecum and Nigella sativa seeds in the management of diabetes-induced in albino rats. J Food Sci. 2024 Jul;89(7):4522-4534. doi: 10.1111/1750-3841.17155. Epub 2024 Jun 9. PMID: 38853293.

75. Liaqat I, Ibtisam R, Hussain MI, Muhammad N, Andleeb S, Naseem S, Ali A, Latif AA, Ali S, Aftab MN, Bibi A, Khalid A. Medicinal Plants Exhibited Promising Potential to Inhibit Biofilm Formation by Catheter-Associated Bacteria in UTI Patients from Lahore, Pakistan. J Oleo Sci. 2025;74(2):221-232. doi: 10.5650/jos.ess24212. PMID: 39880641.

76. Omran SA, Ghani BA. Effect of fenugreek oil on healing of experimentally induced buccal mucosal ulcer by immunohistochemical evaluation of Ki-67 expression. Cell Biochem Biophys. 2024 Sep;82(3):2363-2371. doi: 10.1007/s12013-024-01347-0. Epub 2024 Jun 13. PMID: 38869686.

77. Sekhar MG, Ramudu Shanmugam K, Chakrapani IS. Trigonelline, a Fenugreek Bioactive compound protects Heart tissue against alcohol intoxication: An in-vivo study focusing on antioxidant perspective. J Ayurveda Integr Med. 2024 Jul-Aug;15(4):100963. doi: 10.1016/j.jaim.2024.100963. Epub 2024 Aug 7. PMID: 39116705; PMCID: PMC11350489.

78. Faturoti AO, Ogidi CO. Inclusion of antimicrobial and antioxidant spices into milk candy towards enhancement of nutrient contents and bio-functional activities. Heliyon. 2025 Jan 27;11(3):e42249. doi: 10.1016/j.heliyon.2025.e42249. PMID: 39959487; PMCID: PMC11830343.

79. Erten F, Er B, Ozmen R, Tokmak M, Gokdere E, Orhan C, Morde AA, Padigaru M, Sahin K. Effects of Integrated Extracts of *Trigonella foenum-graecum* and *Asparagus racemosus* on Hot Flash-like Symptoms in Ovariectomized Rats. Antioxidants (Basel). 2025 Mar 18;14(3):355. doi: 10.3390/antiox14030355. PMID: 40227409; PMCID: PMC11939183.

80. De A, Mishra S. Synthesis of fenugreek gum-based metal-organic framework (FG/Zr-AIPA MOF) composite beads for sequestration of heavy metal ions from aqueous solution. Environ Sci Pollut Res Int. 2024 May;31(22):32571-32587. doi: 10.1007/s11356-024-33315-9. Epub 2024 Apr 24. PMID: 38656722.

81. Sadan M, Naem M, Tawfeek HM, Khodier MM, Zeitoun MM, El-Khodery S, Alkhamiss AS, Hassan YAH, Abdellatif AAH. Can silver nanoparticles stabilized by Fenugreek (*Trigonella foenm -graecum*) improve tibial bone defects repair in rabbits? A preliminary study. Open Vet J. 2024 May;14(5):1281-1293. doi: 10.5455/OVJ.2024.v14.i5.23. Epub 2024 May 31. PMID: 38938444; PMCID: PMC11199762.

82. Sharma S, Sharma P, Singh J, Bahel S, Dutta R, Vig AP, Katnoria JK. Assessing cell viability and genotoxicity in Trigonella foenum-graecum L. exposed to 2100 MHz and 2300 MHz electromagnetic field radiations. Plant Physiol Biochem. 2025 Feb;219:109311. doi: 10.1016/j.plaphy.2024.109311. Epub 2024 Nov 19. PMID: 39612822.

83. Subbuvel M, Mohan R, Dubey U, Gopalaswamy Pillai UT, Kavan P. Fabrication of nutritional edible bowls with wheat bran, multigrain powder, refined flour, flax seed powder, fenugreek essential oil, and jaggery. J Sci Food Agric. 2025 Mar 30;105(5):2836-2842. doi: 10.1002/jsfa.14057. Epub 2024 Dec 5. PMID: 39633239.

84. Kemper L, Herrmann F, König S, Falcone FH, Hensel A. Galactomannan and Vicilin from Fenugreek Seeds (Trigonella foenum-graecum) Impair Early Pathogen-Host Interaction of Campylobacter jejuni with Intestinal Cells via JlpA. Planta Med. 2025 Apr;91(5):293-301. doi: 10.1055/a-2536-8392. Epub 2025 Feb 10. PMID: 39929245.

85. Shahzad MA, Younis U, Ehsan A, Alarfaj AA, Alharbi SA, Ansari MJ. Impact of gibberellic acid GA3, quantum dot biochar, and rhizosphere bacteria on fenugreek plant growth and stress responses under lead stress. Sci Rep. 2024 Nov 28;14(1):29612. doi: 10.1038/s41598-024-81072-z. PMID: 39609486; PMCID: PMC11604958.

86. Dahab AA, Bayomy HM, El-Salam HSA, Almasoudi SE, Ozaybi NA, Mahmoud GA, Atteya AKG, El-Serafy RS. Seed Disinfection Treatments Minimized Microbial Load and Enhanced Nutritional Properties of Fenugreek Sprouts Which Alleviated Diabetes-Negative Disorders in Diabetic Rats. Nutrients. 2024 Aug 10;16(16):2635. doi: 10.3390/nu16162635. PMID: 39203772; PMCID: PMC11357563.

87. Hachouf M, Aouacheri O, Saka S, Marzocchi A, Carlo Tenore G. Phenolic Profiling, In Vitro Antiglycation, Antioxidant Activities, and Antidiabetic Effect of Algerian Trigonella Foenum-Graecum L. in Rats Administered a β-Cell Toxicant. Chem Biodivers. 2025 Jan;22(1):e202401183. doi: 10.1002/cbdv.202401183. Epub 2024 Oct 31. PMID: 39269990.

88. Khalil AM, Sabry OM, El-Askary HI, El Zalabani SM, Eltanany BM, Pont L, Benavente F, Elshewy A, Fayek NM. Identification of cyclooxygenase-II inhibitory saponins from fenugreek wastes: Insights from liquid chromatography-tandem mass spectrometry metabolomics, molecular networking, and molecular docking. Phytochem Anal. 2024 Jun;35(4):690-707. doi: 10.1002/pca.3322. Epub 2024 Jan 11. PMID: 38212263.

89. Jambor T, Goc Z, Zuscikova L, Greifova H, Kovacik A, Kovacikova E, Pec M, Lukac N. Phytochemical Screening and Monitoring of Intercellular Changes in Murine Leydig Cells After the Treatment of Trigonella foenum-graecum L. Microgreens In Vitro. Physiol Res. 2025 Mar 24;74(1):115-128. doi: 10.33549/physiolres.935484. PMID: 40126148; PMCID: PMC11995942.

90. Babaei MJ, Ebrahimi A, Heidari P, Azadvari E, Gharanjik S, Chaghakaboodi Z. Titanium dioxide -mediated regulation of enzymatic and non-enzymatic antioxidants, pigments, and diosgenin content promotes cold stress tolerance in Trigonella foenum-graecum L. Sci Rep. 2025 Jan 13;15(1):1837. doi: 10.1038/s41598-024-84472-3. PMID: 39805881; PMCID: PMC11730625.

91. Naaz N, Choudhary S, Hasan N, Sharma N, Al Aboud NM, Shehata WF. Biochemical and molecular profiling of induced high yielding M3 mutant lines of two Trigonella species: Insights into improved yield potential. PLoS One. 2024 Jul 29;19(7):e0305691. doi: 10.1371/journal.pone.0305691. PMID: 39074097; PMCID: PMC11285971.

92. Mate PS, Verma VC, Agrawal S, Jaiswal JP, Kumari VV, Kumar R, Kumari M, Gaber A, Hossain A. Effect of fenugreek (Trigonella foenum-graecum L.) seed extract on glycemic index, in vitro digestibility, and physical characterization of wheat (Triticum aestivum L.) starch. J Food Sci. 2024 Nov;89(11):7626-7639. doi: 10.1111/1750-3841.17411. Epub 2024 Sep 26. PMID: 39327545.

93. Prosad Banik S, Kumar P, Bagchi D, Paul S, Goel A, Bagchi M, Chakraborty S. Fenfuro®-mediated arrest in the formation of protein-methyl glyoxal adducts: a new dimension in the anti-hyperglycemic potential of a novel fenugreek seed extract. Toxicol Mech Methods. 2024 Oct;34(8):877-885. doi: 10.1080/15376516.2024.2358520. Epub 2024 Jun 4. PMID: 38832450.

94. Khorrami M, Samsampour D, Badi HN, Qaderi A. Genetic and phytochemical evaluation of M2 generation mutants of fenugreek (Trigonella foenum-graecum L.) induced by gamma rays and Ethyl Methane Sulphonate (EMS). Mol Biol Rep. 2024 Nov 14;51(1):1154. doi: 10.1007/s11033-024-10090-x. PMID: 39541037.

95. Rath P, Prakash D, Ranjan A, Chauhan A, Jindal T, Alamri S, Alamri T, Harakeh S, Haque S. Modulation of Insulin Resistance by Silybum marianum Leaves, and its Synergistic Efficacy with Gymnema sylvestre, Momordica charantia, Trigonella-foenum graecum Against Protein Tyrosine Phosphatase 1B. Biotechnol Genet Eng Rev. 2024 Dec;40(4):3805-3827. doi: 10.1080/02648725.2022.2162236. Epub 2023 Jan 14. PMID: 36641593.

96. Muluye D, Getachew P, Tekalign T, Woldekidan S, Biftu T. Evaluation of the antihyperglycemic and antihyperlipidemic effects of *Trigonella foenum-graecum* L and *Coffea arabica* L seeds in STZ induced diabetic mice: impact on kidney and liver functions. Pan Afr Med J. 2024 Nov 27;49:94. doi: 10.11604/pamj.2024.49.94.44735. PMID: 40060282; PMCID: PMC11889442.

97. Shaaban A, Hemida KA, Abd El-Mageed TA, Semida WM, AbuQamar SF, El-Saadony MT, Al-Elwany OAAI, El-Tarabily KA. Incorporation of compost and biochar enhances yield and medicinal compounds in seeds of water-stressed Trigonella foenum-graecum L. plants cultivated in saline calcareous soils. BMC Plant Biol. 2024 Jun 12;24(1):538. doi: 10.1186/s12870-024-05182-6. PMID: 38867179; PMCID: PMC11167906.

98. Kumar A, Singh N. Embracing nutritional, physical, pasting, textural, sensory and phenolic profile of functional muffins prepared by partial incorporation of lyophilized wheatgrass, fenugreek and basil microgreens juice powder. J Sci Food Agric. 2024 May;104(7):4286-4295. doi: 10.1002/jsfa.13314. Epub 2024 Feb 2. PMID: 38308402.

99. Almuzaini NAM, Sulieman AME, Alanazi NA, Badraoui R, Abdallah EM. Mass Spectrometric Based Metabolomics of the Saudi Cultivar of Fenugreek (*Trigonella foenum-graecum* L.): A Combined GC-MS, Antimicrobial and Computational Approach. Pharmaceuticals (Basel). 2024 Dec 21;17(12):1733. doi: 10.3390/ph17121733. PMID: 39770575; PMCID: PMC11677947.

100. Ashour M, Khairy HM, Bakr A, Matter M, Alprol AE. Seaweed liquid extract AS novel sustainable solutions for phycobioremediation plant germination, and feed additive for marine invertebrate copepod. Sci Rep. 2024 Nov 28;14(1):29553. doi: 10.1038/s41598-024-80389-z. PMID: 39609572; PMCID: PMC11605070.