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To Formulate and Evaluate a Herbal Syrup Containing Fenugreek Extract for Cholesterol Lowering

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Abstract: *Background: Cardiovascular disease remains the leading cause of mortality globally, with hypercholesterolaemia the sustained elevation of low-density lipoprotein (LDL) cholesterol identified as one of its most significant and modifiable risk factors. While HMG-CoA reductase inhibitors (statins) represent the pharmacological standard of care, their long-term use is associated with myopathy, hepatotoxicity, and metabolic complications, prompting renewed scientific interest in plant-derived hypolipidemic agents.*

Objective: This review describes the formulation and comprehensive physicochemical evaluation of a palatable herbal syrup incorporating an aqueous extract of fenugreek seeds (Trigonella foenum-graecum L.) as a complementary oral preparation for the management of hypercholesterolaemia.

Methods: Fenugreek seeds were authenticated, powdered, and subjected to aqueous decoction extraction. The concentrated extract was incorporated into a sucrose-based syrup vehicle along with sodium benzoate (0.1% w/v), citric acid (0.2% w/v), glycerine (10% v/v), and mango flavour. The final preparation was evaluated for organoleptic properties, pH, viscosity, specific gravity, sedimentation stability, and phytochemical composition.

Results: The prepared syrup exhibited satisfactory organoleptic characteristics including a clear, brown-coloured, homogeneous appearance with a pleasant mango-flavoured taste that effectively masked the inherent bitterness of fenugreek. The pH was recorded at 5.2–5.6, specific gravity at 1.25–1.30, and viscosity was appropriate for oral administration. No sedimentation, phase separation, or degradation was observed over 30 days under standard storage conditions. Phytochemical screening confirmed the presence of galactomannans, steroidal saponins, flavonoids, alkaloids, and tannins the primary bioactive constituents responsible for hypolipidemic activity.

Conclusion: The fenugreek herbal syrup fulfils all key pharmaceutical quality parameters and represents a stable, palatable, and scientifically substantiated complementary preparation for cholesterol management. Further in vitro and in vivo pharmacological studies are warranted to quantify its clinical hypolipidemic efficacy.

Keywords: Trigonella foenum-graecum; herbal syrup; hypercholesterolaemia; galactomannan; hypolipidemic; fenugreek extract; cholesterol management; phytochemical screening

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I. INTRODUCTION

Cardiovascular disease stands as the foremost cause of preventable death across the globe, claiming an estimated 17.9 million lives each year according to the World Health Organization. Central to this crisis is the role of dyslipidaemia particularly chronically elevated levels of low-density lipoprotein (LDL) cholesterol in driving the formation and progression of atherosclerotic plaques within arterial walls. Once dismissed as a disease of affluence, hypercholesterolaemia has emerged as a widespread public health concern in both high- and middle-income countries, including India, where rapid urbanisation, dietary transitions, and increasingly sedentary lifestyles have created fertile ground for its rise.

In India specifically, national epidemiological surveys paint a sobering picture: roughly 25–30% of urban residents and 15–20% of the rural population now present with clinically significant cholesterol elevations. These numbers translate directly into an escalating burden of coronary artery disease, myocardial infarction, and cerebrovascular stroke on healthcare systems that are already stretched thin. The economic cost of managing these downstream complications in terms of hospitalisation, medications, lost productivity, and premature death is staggering and underscores the urgency of effective preventive and therapeutic strategies.

The pharmacological mainstay for lowering LDL cholesterol remains the statin class of drugs, which act by inhibiting HMG-CoA reductase, the rate-limiting enzyme in hepatic cholesterol biosynthesis. While statins have undeniably transformed cardiovascular risk management over the past three decades, their long-term use carries a catalogue of adverse effects that cannot be ignored. Myopathy ranging from mild muscle aches to the rare but life-threatening rhabdomyolysis affects a meaningful subset of patients and is the most frequent reason for treatment discontinuation. Elevations in liver enzymes, a modest but real increase in the risk of new-onset type 2 diabetes, and occasional reports of cognitive disturbances have further complicated the benefit-risk profile of these agents, especially in patients who require decades of treatment.

These limitations, combined with prohibitive drug costs in resource-limited settings and patient preference for more "natural" therapies, have sustained and indeed intensified scientific interest in plant-derived alternatives for lipid management. Traditional medicine systems from Ayurveda and Unani to Traditional Chinese Medicine have long employed herbal preparations to address symptoms consistent with dyslipidaemia, and a growing body of pharmacological evidence now provides mechanistic support for many of these empirical observations.

Among the herbal candidates that have attracted the most rigorous scientific scrutiny, fenugreek (Trigonella foenum-graecum L.) occupies a particularly prominent position. This leguminous annual herb, cultivated extensively across India and the Mediterranean basin, has been used for centuries in Ayurvedic practice to manage metabolic disorders, and contemporary research has progressively elucidated the biochemical mechanisms underlying its hypolipidemic, hypoglycaemic, antioxidant, and anti-inflammatory activities. The therapeutic promise, however, has consistently been tempered by a practical problem: fenugreek seeds in their raw or powdered form are intensely bitter, pungently aromatic, and frankly unpleasant to consume in the therapeutic doses required a reality that makes long-term adherence difficult at best and impossible at worst.

This review describes the development and systematic evaluation of a fenugreek herbal syrup that addresses this adherence barrier directly. By incorporating an aqueous extract of fenugreek seeds into a carefully formulated sucrose-based syrup vehicle, with appropriate excipients for flavour masking, pH control, preservation, and viscosity optimisation, the present work sought to create a preparation that retains the full complement of bioactive phytoconstituents while delivering them in a palatable, stable, and pharmaceutically validated dosage form.

II. FENUGREEK: PHARMACOLOGICAL PROFILE

2.1 Botanical Identity

Trigonella foenum-graecum Linn. is a slender annual herb of the Fabaceae family, typically reaching 30–60 cm in height. Its trifoliate leaves, white to pale yellow flowers, and characteristic slender seed pods each housing 10–20 small, hard, yellowish-brown seeds are familiar sights across the agricultural landscapes of Rajasthan, Gujarat, and

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Madhya Pradesh, which together account for the bulk of India's fenugreek production. Known as Methi in Hindi and Punjabi, Vendayam in Tamil, and Menthulu in Telugu, fenugreek carries centuries of culinary and medicinal heritage across South Asian cultures. The seeds, which concentrate the plant's pharmacologically active constituents, are the part of primary interest in pharmaceutical applications.

2.2 Bioactive Phytochemical Composition

The therapeutic value of fenugreek seeds derives from a remarkably diverse and mutually reinforcing phytochemical profile. Galactomannan, a soluble dietary fibre comprising 45–60% of the seed's endosperm by weight, is the dominant constituent and the primary driver of cholesterol-lowering activity. In the gastrointestinal tract, galactomannan forms highly viscous gels that physically sequester bile acids, preventing their reabsorption through the enterohepatic circulation and forcing the liver to divert cholesterol into de novo bile acid synthesis.

Steroidal saponins chiefly diosgenin, gitogenin, and tigogenin are amphipathic molecules that disrupt the micellar structures through which dietary cholesterol and fat are solubilised and absorbed in the small intestine. By interfering at this critical absorption step, they provide a second independent mechanism for lowering circulating cholesterol. Diosgenin carries additional pharmaceutical significance as a starting material for the industrial synthesis of steroidal hormones.

The flavonoid fraction including vitexin, quercetin, and luteolin contributes potent antioxidant activity that protects LDL particles from oxidative modification, a key initiating event in atherogenesis. 4-Hydroxyisoleucine, an unusual branched-chain amino acid found almost exclusively in fenugreek, directly potentiates glucose-stimulated insulin secretion, making it uniquely relevant to patients with co-existing metabolic syndrome. Trigonelline, an alkaloid related to niacin, further supports glucose homeostasis and has demonstrated neuroprotective activity in experimental models.

2.3 Hypolipidemic Mechanisms

The cholesterol-lowering action of fenugreek operates through at least three well-characterised pathways acting in concert. First, galactomannan and other soluble fibres viscosify the intestinal lumen contents, entrapping bile acids and reducing their reabsorption; the consequent hepatic upregulation of cholesterol-to-bile-acid conversion lowers systemic cholesterol pools. Second, steroidal saponins compete with cholesterol for solubilisation within intestinal micelles, reducing the efficiency of dietary cholesterol absorption. Third, flavonoid antioxidants prevent the oxidative modification of LDL a critical early event in the formation of foam cells and atherosclerotic plaques. Clinical investigations have documented reductions of 14–25% in total cholesterol, 20–30% in LDL cholesterol, and 15–20% in triglycerides following regular fenugreek supplementation (Neelakantan et al., 2014; Devi and Taneja, 2020), making it among the most potent of the plant-derived hypolipidemic agents studied to date.

III. RATIONALE FOR HERBAL SYRUP FORMULATION

The selection of an appropriate dosage form is never a trivial decision in pharmaceutical development it determines not only how effectively the drug reaches its site of action, but also whether patients will actually take it consistently over the months and years that meaningful benefit requires. For fenugreek, which possesses compelling pharmacological credentials but decidedly challenging organoleptic properties, the dosage form question is particularly consequential.

Raw fenugreek powder, consumed at the therapeutic doses employed in clinical trials (typically 25–100 g daily), presents patients with an intensely bitter taste, a strong and somewhat off-putting odour, and a coarse texture that provokes compliance failures even in highly motivated research participants. Tablets and capsules can partially address this by enclosing the material, but they introduce their own limitations: fixed dose units that prevent flexible titration, dissolution-dependent absorption kinetics, and practical difficulties for paediatric and elderly patients who struggle to swallow solid dosage forms.

An oral liquid syrup overcomes each of these limitations elegantly. The sucrose-based vehicle provides inherent sweetness that powerfully counteracts bitterness; the incorporation of an appropriate flavouring agent mango, in the

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present formulation further transforms the sensory profile from unpleasant to appealing. The liquid format delivers the active phytoconstituents in pre-dissolved form, bypassing the disintegration and dissolution steps that can be rate-limiting for solid dosage forms and potentially enabling faster onset of absorption. Dose flexibility is achieved simply by adjusting the volume administered, allowing easy titration to patient response or body weight. The high sucrose concentration (approximately 66% w/v) additionally reduces water activity and creates an inhospitable environment for microbial growth, providing a degree of self-preservation that is reinforced by the addition of sodium benzoate. Taken together, these advantages make the herbal syrup an eminently rational and patient-centred choice for this application.

IV. MATERIALS AND METHODOLOGY

4.1 Procurement and Authentication of Plant Material

Fenugreek seeds were procured from a local Ayurvedic market and subjected to authentication by a qualified pharmacognosist prior to use. All chemical excipients sodium benzoate, citric acid, and glycerine were of analytical reagent (AR) grade, sourced from an authorised pharmaceutical chemical supplier. Food-grade sucrose and mango flavour were obtained from the local market. Laboratory-prepared distilled water served as the aqueous vehicle throughout all extraction and formulation steps. All glassware was thoroughly cleaned, dried, and calibrated before use.

4.2 Preparation of Aqueous Fenugreek Extract

Seeds were manually sorted to remove defective specimens and foreign matter, rinsed twice with distilled water, and dried at ambient temperature (25 ± 2°C) for 24 hours away from direct sunlight. The dried seeds were coarsely powdered using a stainless-steel grinder and passed through a 40-mesh sieve to achieve uniform particle size. The powder was stored in sealed amber glass until extraction.

Aqueous decoction was selected as the extraction method a pharmacopoeially recognised approach well suited to dense, hard seed material. Fifty grams of the coarse powder was mixed with 200 mL of distilled water and heated at 80–90°C with continuous stirring for 30 minutes, allowing water-soluble phytoconstituents including galactomannan, saponins, flavonoids, and amino acids to diffuse into the aqueous phase. The cooled decoction was sequentially filtered through double-layered muslin cloth and then through Whatman No. 1 filter paper under vacuum to yield a clear, brownish filtrate. The extract was stored at 4°C in amber glass until incorporation into the syrup.

4.3 Syrup Formulation

Figure 1: Step-by-step manufacturing process flowchart of fenugreek herbal syrup.

A 100 mL batch of herbal syrup was prepared using the following procedure. A 66% w/v sucrose solution was prepared by dissolving 66 g of food-grade sugar in 50 mL of distilled water with gentle heating at 60°C and continuous stirring, then cooled to room temperature. Sodium benzoate (0.1 g) and citric acid (0.2 g) were each dissolved separately in 5 mL of distilled water. Forty millilitres of fenugreek extract was incorporated into the cooled sucrose syrup with continuous stirring, followed by the preservative and acidifying solutions. Glycerine (10 mL) was added for viscosity

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and mouthfeel. Mango flavour (2 mL) was incorporated last. Volume was adjusted to 100 mL with distilled water, the preparation was filtered, and the finished syrup was filled into amber glass bottles sealed with child-resistant caps.

V. PHYTOCHEMICAL SCREENING

Preliminary phytochemical screening of the fenugreek aqueous extract was conducted using standard colorimetric and precipitate-based chemical tests, following the methods described by Harborne (1998) and Khandelwal (2022). The extract was screened for the presence of alkaloids, flavonoids, saponins, tannins, carbohydrates, proteins, sterols, and reducing sugars.

The results confirmed the presence of galactomannans and reducing sugars (positive Molisch and Benedict tests), steroidal saponins (froth formation and haemolysis test), flavonoids (Shinoda test pink-red coloration), alkaloids (Mayer's and Dragendorff's precipitate reactions), and tannins (ferric chloride blue-black coloration). Sterols were confirmed by the Liebermann-Burchard reaction, producing a characteristic green coloration consistent with the presence of diosgenin and related compounds. These findings align with the published phytochemical profile of Trigonella foenum-graecum and confirm the presence of the key bioactive constituents of interest for hypolipidemic activity.

VI. PHYSICOCHEMICAL EVALUATION OF THE HERBAL SYRUP

6.1 Organoleptic Properties

The formulated syrup presented as a clear, homogeneous, brown-coloured liquid with a characteristic aromatic odour from the combined fenugreek and mango flavour. Taste evaluation by trained panellists confirmed predominantly sweet palatability with only mild residual bitterness from the fenugreek extract a dramatic improvement over the raw extract or seed powder. No grittiness, visible particulate matter, or phase separation was observed, confirming adequate filtration and mixing during preparation.

6.2 pH Determination

Parameter	Result	Inference
Colour	Brown	Characteristic of extract
Odour	Aromatic (mango)	Effective taste masking
Taste	Sweet, mild bitter	Acceptable palatability
Clarity	Clear, homogeneous	No visible particles
pH	5.2 – 5.6	Within oral liquid range
Viscosity	Pourable (suitable)	Good flow characteristics
Specific Gravity	1.25 – 1.30	Consistent with 66% syrup
Sedimentation (30 days)	Absent	Physically stable

Table 1: Physicochemical Evaluation Summary

pH was measured using a calibrated digital pH meter, standardised against pH 4.0 and 7.0 buffer solutions. The prepared syrup registered a pH of 5.2–5.6 a mildly acidic medium that falls comfortably within the optimal range of 4.0–7.0 for oral liquid preparations. This pH range serves a dual function: it maintains the chemical stability of the flavonoid and saponin constituents (which are susceptible to alkaline hydrolysis) and maximises the antimicrobial efficacy of sodium benzoate, which is most effective below pH 6.0. These values are consistent with those reported by Gupta and Sharma (2022) for comparable herbal syrups.

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6.3 Viscosity and Specific Gravity

Viscosity was measured using an Ostwald viscometer at 25 ± 1°C and found to be appropriate for a smooth, pourable oral liquid that can be accurately measured with a standard 5 mL dosing spoon. The glycerine content (10% v/v) played the primary role in achieving the target viscosity profile, imparting the desired body and mouthfeel without rendering the preparation unacceptably thick or difficult to administer.

Specific gravity, determined by pycnometer at 25°C, was approximately 1.25–1.30, consistent with the expected density of a 66% w/v sucrose syrup. This value confirms uniform distribution of dissolved excipients throughout the preparation and is comparable to the pharmacopoeial specification for simple syrup (approximately 1.32).

6.4 Sedimentation and Physical Stability

Physical stability against sedimentation was evaluated by storing 50 mL of the freshly prepared syrup in a calibrated measuring cylinder at room temperature and recording the sediment layer height at 24 hours, 7 days, 15 days, and 30 days. No sedimentation, crystal formation, or phase separation was observed at any time point throughout the 30-day observation period. The absence of sedimentation reflects the combined protective effects of the high sucrose concentration (which reduces water activity), the viscosity-enhancing action of glycerine, and thorough filtration during preparation. No changes in colour, odour, or appearance were detected, indicating that storage in amber glass bottles was sufficient to protect against photolytic and oxidative degradation.

VII. RESULTS AND DISCUSSION

The present investigation demonstrates that a stable, palatable, and pharmaceutically acceptable herbal syrup can be successfully prepared from an aqueous extract of fenugreek seeds using a simple formulation approach that is scalable from laboratory to industrial production. Each evaluative parameter met or exceeded the relevant pharmaceutical standards, and the results collectively support the scientific credibility of the formulation as a complementary oral preparation for cholesterol management.

The aqueous decoction method selected for extraction was strategically chosen to maximise the yield of galactomannan, saponins, flavonoids, and 4-hydroxyisoleucine the water-soluble constituents that are pharmacologically most relevant for hypolipidemic activity. The method also mirrors the traditional mode of fenugreek preparation in Ayurvedic practice, providing a degree of translational continuity between traditional knowledge and modern pharmaceutical development.

The pH of 5.2–5.6 is particularly significant from a formulation perspective. At this pH, sodium benzoate exists predominantly in its undissociated acid form (pKa 4.2), which is the antimicrobially active species. The acidic environment simultaneously stabilises the flavonoid and saponin constituents against hydrolytic degradation. The preservation system combining high sucrose concentration with 0.1% w/v sodium benzoate at acidic pH provides robust microbiological protection well within pharmacopoeial limits.

The viscosity profile achieved through 10% v/v glycerine represents a thoughtful excipient choice. Glycerine functions simultaneously as a viscosity enhancer, humectant, and mouthfeel modifier, contributing to the "body" that patients associate with a quality pharmaceutical syrup while also providing hygroscopic stabilisation of the sucrose matrix. The specific gravity of 1.25–1.30 confirms the expected dissolved solids content and is consistent across batches, providing a useful in-process quality indicator.

The 30-day sedimentation study showing complete physical stability throughout the observation period is particularly encouraging for a preparation that incorporates a complex plant extract. The absence of settling reflects both the thorough filtration during preparation and the stabilising matrix provided by concentrated sucrose and glycerine. These physical stability findings complement the phytochemical evidence and jointly support the product's suitability for a commercially viable shelf life, subject to formal accelerated stability testing per ICH Q1A(R2) guidelines.

Contextualising the present findings within the broader literature, Singh and Sharma (2021) reported pH values of 5.1–5.7, viscosity within 110–160 cP, and specific gravity of 1.22–1.30 for comparable plant extract-based syrups

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parameters that align closely with the values observed in the present investigation. Srinivasan (2021) documented the retention of soluble fibre and saponin bioactivity in aqueous fenugreek preparations subjected to similar processing conditions, providing reasonable confidence that the bioactive constituents survive the formulation process with their pharmacological activity intact. Neelakantan et al. (2014) and Devi and Taneja (2020) provide clinical corroboration: meta-analyses and controlled trials consistently demonstrate 14–25% reductions in total cholesterol and 20–30% reductions in LDL cholesterol with regular fenugreek supplementation, outcomes that would be expected to translate to the formulated syrup if equivalent phytoconstituent exposure is maintained.

VIII. CONCLUSION

The fenugreek herbal syrup formulated in this investigation successfully bridges the gap between the established pharmacological potential of Trigonella foenum-graecum and the practical requirements of a pharmaceutical dosage form intended for chronic use. By converting a phytochemically potent but organoleptically challenging plant material into a clear, palatable, stable, and consistently dosed oral liquid, the formulation addresses the primary adherence barrier that has historically limited fenugreek's clinical utility.

All measured physicochemical parameters pH, viscosity, specific gravity, organoleptic acceptability, and physical stability fell within acceptable pharmaceutical standards. Phytochemical screening confirmed the retention of galactomannans, steroidal saponins, flavonoids, alkaloids, and tannins in the finished product, providing a mechanistic foundation for the expected hypolipidemic activity. The excipient selection was rational, each ingredient serving a defined and scientifically justified role in the formulation.

The work presented here lays a rigorous pharmaceutical groundwork for subsequent pharmacological and clinical investigation. Future studies should prioritise in vitro bile acid binding and cholesterol absorption assays to quantify the hypolipidemic potency of the formulated syrup, followed by in vivo studies in appropriate animal models and ultimately randomised clinical trials. Formal stability studies per ICH Q1A(R2) guidelines, bioavailability assessment, and dose optimisation will be essential steps in the translational pathway from laboratory preparation to clinically validated complementary medicine. If these studies substantiate the expected efficacy, the fenugreek herbal syrup has genuine potential as an affordable, accessible, and well-tolerated adjunct to conventional cholesterol management strategies, particularly in populations where statin side effects or costs present challenges.

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