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Formulation and Evaluation of Antidiabetic Herbal Syrup Containing Insulin Plant, Fennel Plant and Stevia Plant Extracts

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Abstract:

Diabetes mellitus is a chronic metabolic disorder requiring safe and effective long-term management strategies. Herbal formulations are increasingly explored due to their traditional usage and favourable safety profiles. The present study aimed to formulate and evaluate a polyherbal antidiabetic syrup containing extracts of Costus igneus, Foeniculum vulgare, and Stevia rebaudiana. The selected plants were processed and subjected to preliminary phytochemical screening. A stable syrup formulation was developed and evaluated for organoleptic properties, pH, viscosity, specific gravity, and short-term stability. Phytochemical analysis confirmed the presence of bioactive constituents such as flavonoids and phenolic compounds associated with glycaemic regulation. The formulated syrup exhibited acceptable physicochemical characteristics and remained stable under storage conditions. The study successfully demonstrates the development of standardised polyherbal syrup which may serve as a supportive herbal preparation for glycaemic management.

Key words: costus igneus; diabetes mellitus; dysphagia; foeniculum vulgare; herbal syrup; stevia rebaudiana.

Introduction:

Diabetes mellitus is a chronic metabolic disorder characterised by sustained hyperglycaemia resulting from defects in insulin secretion, insulin action, or both. Persistent elevation of blood glucose leads to metabolic dysregulation, oxidative stress, chronic low-grade inflammation, and progressive tissue damage. Long-term complications include neuropathy, nephropathy, retinopathy, and cardiovascular disorders, making effective glycaemic management a primary therapeutic objective. Although synthetic hypoglycaemic agents and insulin therapy remain the mainstay of treatment, long-term pharmacotherapy is often associated with adverse effects, economic burden, and reduced patient adherence. Consequently, there is growing interest in complementary and plant-based formulations that may support metabolic regulation with improved safety profiles. [1-4]

Medicinal plants represent a valuable source of bioactive compounds capable of modulating multiple pathways involved in glucose homeostasis. Phytoconstituents such as flavonoids, phenolic acids, terpenoids, and glycosides have been reported to influence carbohydrate metabolism, improve antioxidant defence systems, and enhance insulin sensitivity. Unlike single-molecule synthetic drugs, herbal preparations contain diverse secondary metabolites that may act through complementary or synergistic mechanisms. Polyherbal formulations, in particular, are traditionally believed to enhance therapeutic efficacy by targeting multiple aspects of metabolic imbalance simultaneously.[5]

Costus igneus, commonly referred to as the “insulin plant,” has been traditionally consumed in various regions for glycaemic control. Experimental investigations have suggested that its bioactive constituents may contribute to improved glucose utilisation and antioxidant activity. Foeniculum vulgare (fennel) is rich in phenolic compounds and essential oils, which have been associated with antioxidant and

digestive-modulating properties that may indirectly influence carbohydrate metabolism. Stevia rebaudiana, widely recognised as a natural non-caloric sweetener, contains steviosides and rebaudiosides that provide sweetness without elevating blood glucose levels and have been reported to exhibit insulinotropic and glucose-modulating effects. The integration of these three botanicals offers a rational Phyto therapeutic approach combining metabolic support, antioxidant potential, and glycaemic safety. [6-13]

In addition to pharmacological efficacy, the selection of an appropriate dosage form is a critical determinant of therapeutic acceptability and patient compliance. Liquid formulations such as syrups offer significant advantages in herbal drug delivery, including enhanced palatability, uniform distribution of phytoconstituents, ease of administration, and suitability for dose flexibility. Syrup dosage forms are particularly beneficial for paediatric and geriatric populations, as well as patients suffering from dysphagia a clinical condition characterised by difficulty in swallowing solid oral medications. Dysphagia is frequently observed in elderly individuals and in patients with neurological or systemic disorders, where administration of tablets or capsules may compromise compliance and accurate dosing. In such circumstances, liquid preparations improve adherence and ensure consistent therapeutic intake.14-16 However, the successful development of a polyherbal syrup requires systematic formulation design, optimisation of excipient compatibility, and comprehensive physicochemical evaluation to ensure stability, uniformity, and overall quality of the final product. Despite increasing interest in herbal antidiabetic preparations, limited scientific literature is available on the formulation and systematic evaluation of a polyherbal syrup combining Costus igneus, Foeniculum vulgare, and Stevia rebaudiana. Most available studies focus either on individual plant extracts or on solid dosage forms, with insufficient emphasis on liquid polyherbal systems and their physicochemical standardisation. Therefore, the present study was undertaken to formulate and evaluate a polyherbal antidiabetic syrup incorporating extracts of these selected plants, with particular emphasis on formulation development, phytochemical profiling, and physicochemical characterisation.

Advantages of Syrup Dosage Form

Uncontrolled diabetes manifests through several characteristic clinical features, including:

- Polyuria (frequent urination)
- Polydipsia (excessive thirst)
- Polyphagia (increased appetite)
- Unexplained weight loss
- Fatigue and weakness
- Blurred vision
- Delayed wound healing
- Recurrent infections

Signs and Symptoms of Diabetes:

Chronic hyperglycaemia may lead to serious complications such as neuropathy, nephropathy, retinopathy, and cardiovascular disorders.[17]

Role of Medicinal Plants in Glycaemic Management

Medicinal plants are rich sources of bioactive phytoconstituents including flavonoids, phenolic compounds, alkaloids, terpenoids, and glycosides. These compounds are reported to modulate glucose metabolism, enhance antioxidant defence mechanisms, improve insulin sensitivity, and support pancreatic β-cell function. Owing to their multi-component nature, polyherbal formulations may exert synergistic effects by simultaneously targeting multiple pathways involved in glycaemic regulation.

Ingredients Used in Polyherbal Syrup:

Rationale For Selection of Plants

Costus igneus (Insulin Plant) has been traditionally used for glycaemic control and is reported to exhibit antihyperglycaemic and antioxidant properties that may support glucose homeostasis.

Foeniculum vulgare (Fennel) contains phenolic compounds and essential oils known for their antioxidant and digestive-modulating effects, which may contribute to improved carbohydrate metabolism and metabolic balance.

Stevia rebaudiana (Stevia) is a natural non-caloric sweetener rich in steviosides that provide sweetness without elevating blood glucose levels, thereby enhancing palatability while maintaining glycaemic safety. [6-13]

The combination of these plants offers a rational polyherbal strategy in which Costus igneus primarily supports glycaemic regulation,

Foeniculum vulgare contributes antioxidant and metabolic support, and Stevia rebaudiana ensures sweetness without glycaemic load. Together, their complementary mechanisms may produce a synergistic effect by simultaneously targeting glucose regulation, oxidative stress, and formulation acceptability, thereby enhancing the overall therapeutic potential of the syrup.

Syrup formulations offer several benefits

- Improved palatability
- Ease of administration
- Suitable for paediatric and geriatric patients
- Uniform dispersion of extracts
- Flexible dose adjustment
- Rapid absorption
- Incorporation of Stevia further enhances sweetness without contributing to glycaemic load.[18]

Materials And Methodology:

Plant Materials

Materials

Costus igneus Nak. (Family: Costaceae) Costus igneus, commonly known as the insulin plant, is traditionally used for glycaemic regulation. The leaves contain flavonoids, phenolic compounds, triterpenoids, and alkaloids, which are associated with antihyperglycaemic and antioxidant activities. These bioactive constituents may contribute to improved glucose metabolism and reduction of oxidative stress. In the present formulation, Costus igneus serves as the primary active component for glycaemic support.

Figure 1: *Costus igneus Nak.*

Foeniculum vulgare Mill. (Family: Apiaceae)

Foeniculum vulgare (fennel) contains essential oils such as anethole and fenchone, along with phenolic compounds and flavonoids. It exhibits antioxidant, digestive-modulating, and mild metabolic regulatory effects. Its inclusion in the formulation is intended to provide supportive antioxidant activity and improve overall metabolic balance.

Figure 2*: Foeniculum vulgare Mill.*

Stevia rebaudiana Bertoni (Family: Asteraceae)

Stevia rebaudiana is a natural non-caloric sweetener rich in steviol glycosides, including stevioside and rebaudioside A. It provides sweetness without increasing blood glucose levels and has been reported to exhibit glycaemic safety. In the present formulation, Stevia serves as a natural sweetening agent while maintaining suitability for diabetic use.

Figure 3: *Stevia rebaudiana Bertoni*

Phytochemical Category	*Costus igneus*	*Foeniculum vulgare*	*Stevia rebaudiana*
Flavonoids	Quercetin, Kaempferol	Quercetin, Rutin	Quercetin, Apigenin
Phenolic Compounds	Caffeic acid, Chlorogenic acid	Caffeic acid, Ferulic acid	Chlorogenic acid
Glycosides	Cardiac glycosides	Phenolic glycosides	Stevioside, Rebaudioside A
Terpenoids	Lupeol, β-amyrin	Terpenoids	Diterpene glycosides
Volatile Oils	-	Anethole, Fenchone, Estragole	-
Saponins	Steroidal saponins	-	-
Alkaloids	Minor alkaloidal constituents	Trace	-

Table 1: *Category-wise Phytochemical Constituents of Selected Plants*

Excipient	Description	Biological / Natural Source	Function
Aloe vera gel	Clear, viscous, mucilaginous gel with high water content	Leaf parenchyma of *Aloe barbadensis Miller*	Humectant; Thickening base; Bioactive supportive medium
Acacia gum (Gum arabic)	Pale-yellow brittle tears/powder; highly water-soluble	Dried exudate from *Acacia senegal* or *Acacia seyal*	Natural thickener; Emulsifier; Suspending agent; Stabilizer
Citric acid	White crystalline powder; highly soluble in water	Produced by fermentation (commonly *Aspergillus niger*)	Acidulant; pH adjuster; Buffering agent
Sodium benzoate	White granular crystals; slightly salty taste	Sodium salt of benzoic acid (natural origin from berries; industrially synthesized)	Preservative; Antimicrobial agent
Ascorbic acid (Vitamin C)	Fine white to yellowish crystalline powder; water-soluble	Commercial fermentation of glucose	Antioxidant; Reducing agent; Stabilizer
Natural flavour blend (Fennel + Lemon oil)	Clear to pale-yellow volatile aromatic oils	*Foeniculum vulgare* seeds & *Citrus limon* peel	Flavouring agent; Taste masking agent

Table 2: *Excipient profile for Polyherbal anti-diabetic syrup*

Methodology:

Collection of plant materials:

Fresh leaves of Costus igneus and Stevia rebaudiana, and Foeniculum vulgare were collected from self-cultivated, pesticide-free plants maintained under controlled conditions. The plant materials were washed with distilled water to remove impurities, shade-dried at room temperature, and pulverized into coarse powder. The powdered samples were stored in airtight containers until further use. Botanical identification and authentication of the collected plant samples were performed based on morphological and taxonomical characteristics with the help of standard botanical references. The authenticated plant materials were used for the preparation of extracts and further formulation studies.

Method for maceration extraction: [6-13,19]

Figure 4: *Maceration extraction of herbs*

Preparation of Costus igneus Extract:

Fresh leaves of Costus igneus were collected, washed thoroughly with distilled water to remove adhering impurities, and shade-dried at room temperature for 7-10 days until a constant weight was achieved. The dried leaves were pulverized using a mechanical grinder to obtain coarse powder and stored in airtight containers.

Approximately 10 g of powdered material was subjected to hydroalcoholic extraction using ethanol: water (60:40 v/v) in a ratio of 1:10 (w/v). The mixture was macerated for 48 hours at room temperature with intermittent stirring to facilitate efficient extraction of phytoconstituents. After maceration, the extract was filtered through muslin cloth followed by Whatman No. 1 filter paper.

The filtrate was concentrated using a water bath maintained at 40-50°C to evaporate the ethanol content. Concentration was continued until a semi-solid mass was obtained. The concentrated extract was stored in amber-coloured airtight containers at 4°C until further use.

Preparation of Foeniculum vulgare Extract:

Shade-dried and powdered leaves of Foeniculum vulgare were extracted using the same hydroalcoholic solvent system (ethanol: water 60:40 v/v) by maceration for 72 hours in a 1:10 (w/v) ratio. The extract was filtered and concentrated on a water bath below 50°C to remove ethanol while preserving thermolabile constituents. The semi-solid extract obtained was stored in airtight containers under refrigerated conditions until formulation.

Preparation of Stevia rebaudiana Extract:

Shade-dried leaves of Stevia rebaudiana were powdered and subjected to aqueous extraction by maceration in warm distilled water for 24 hours with occasional stirring. The extract was filtered and concentrated on a water bath below 50°C to obtain a concentrated stevia extract rich in steviol glycosides. The extract was stored in amber-coloured containers at refrigerated temperature until further use.

Evaluation of Extracts by Preliminary Phytochemical Screening [20-23]:

Following extraction of the plant materials by the maceration method, the obtained extracts were subjected to preliminary phytochemical screening to evaluate the presence of major classes of secondary metabolites. The purpose of this analysis was to confirm that the extraction process effectively isolated the bioactive constituents responsible for the pharmacological activity of the selected medicinal plants.

Preliminary phytochemical screening is an essential step in herbal drug research because the therapeutic potential of medicinal plants is largely attributed to the presence of specific phytoconstituents such as flavonoids, phenolic compounds, alkaloids, glycosides, saponins, tannins, terpenoids, and volatile oils. These compounds have been widely reported to exhibit biological activities including antioxidant effects, metabolic regulation, anti-inflammatory action, and glycaemic control. Therefore, identification of these constituents provides a scientific basis for the use of the plant extracts in the formulation of polyherbal preparations.

In the present study, qualitative phytochemical analysis was carried out for the extracts of Costus igneus, Foeniculum vulgare, and Stevia rebaudiana using standard pharmacognostic procedures. Specific chemical reagents were employed to detect different groups of phytochemicals. The tests were performed by adding appropriate reagents to small portions of the extracts and observing the development of characteristic colour changes, precipitate formation, or other visible reactions indicative of the presence of particular phytoconstituents.

For example, Mayer's and Dragendorff's reagents were used to detect alkaloids, ferric chloride test was used for phenolic compounds and tannins, Shinoda test was performed for flavonoids, foam test for saponins, Keller-Killiani test for glycosides, and Salkowski test for terpenoids. In the case of Foeniculum vulgare, the presence of volatile oil was evaluated using organoleptic examination and filter paper test, which indicated the presence of essential oil components responsible for its characteristic aroma. The presence of these phytoconstituents in the respective extracts confirmed that the maceration extraction technique was suitable for recovering the important bioactive compounds from the plant materials. These results also supported the selection of these plants for the development of the polyherbal anti-diabetic syrup formulation.

Thus, preliminary phytochemical screening served as a crucial quality evaluation step to ensure that the extracts contained the necessary chemical constituents prior to their incorporation into the final formulation.

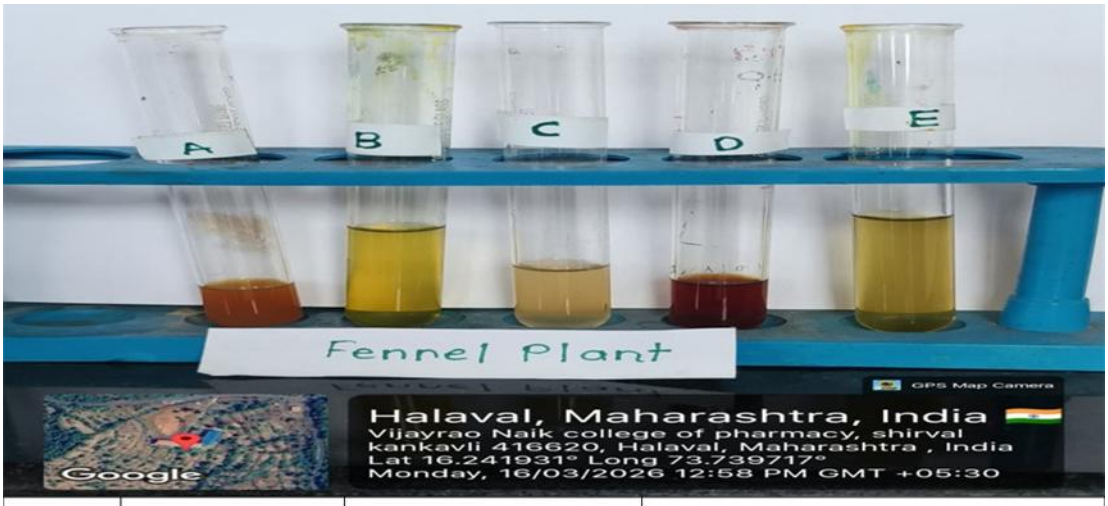
Phytoconstituent	Test Performed	Reagent Used	Observation	Costus igneus	Foeniculum vulgare	Stevia rebaudiana
Alkaloids	Mayer's Test	Mayer's reagent	Cream precipitate formation	+	–	–
	Dragendorff's Test	Dragendorff's reagent	Orange-red precipitate	+	–	–
Flavonoids	Ferric chloride test	Extract sol. + few drops 10% $FeCl_3$	A green precipitate	+	+	+
Phenolic compounds	Iodine Test	Few drops of dil. Iodine sol.	A transient red colour	+	+	+
Tannins	Ferric Chloride Test	10% $FeCl_3$ solution	Blue-black or green coloration	+	+	–
Saponins	Foam Test	Distilled water (vigorous shaking)	Persistent froth formation	+	–	–
Glycosides	Modified Borntrager`s test	Extract + $FeCl_3$ + benzene (equal amount) +Ammonia sol.	Blood red colour	+	–	+
Terpenoids	Salkowski Test	Chloroform + conc. H_2SO_4	Reddish-brown interface	+	+	–
Volatile oils	Filter Paper Test	–	Persistent translucent oily spot	–	+	–

(+) = Present, (–) = Absent

Table 3: *Preliminary Phytochemical Screening of Plant Extracts*

Test Tube	Phytochemical	Test Name	Positive Indication
A	Alkaloids	Dragendorff's Test	Orange or reddish-brown precipitate
B	Cardiac Glycosides	Keller–Kiliani (KK) Test	Brown ring at interface, bluish-green layer
C	Flavonoids	Ferric Chloride Test	Dark green, blue, or black coloration
D	Saponins	Foam Test	Persistent stable foam
E	Tannins	Braymer's Test	Blue-black or greenish coloration
F	Terpenoids	Salkowski Test	Reddish-brown coloration at interface
G	Phenolic Compounds	Iodine Test	Bluish or dark coloration
H	Glycosides	Modified Borntrager's Test	Pink to red coloration in ammoniacal layer

Figure 5: *Preliminary Phytochemical Screening of Insulin Plant*



Test Tube	Phytochemical	Test Name	Positive Indication
A	Alkaloids	Dragendorff's Test	Orange or reddish-brown precipitate
B	Flavonoids	Ferric Chloride Test	Dark green, blue, or black coloration
C	Terpenoids	Salkowski Test	Reddish-brown coloration at interface
D	Phenolic Compounds	Iodine Test	Blue or dark coloration
E	Tannins	Braymer's Test	greenish coloration

Figure 6: *Preliminary Phytochemical Screening of Fennel plant*

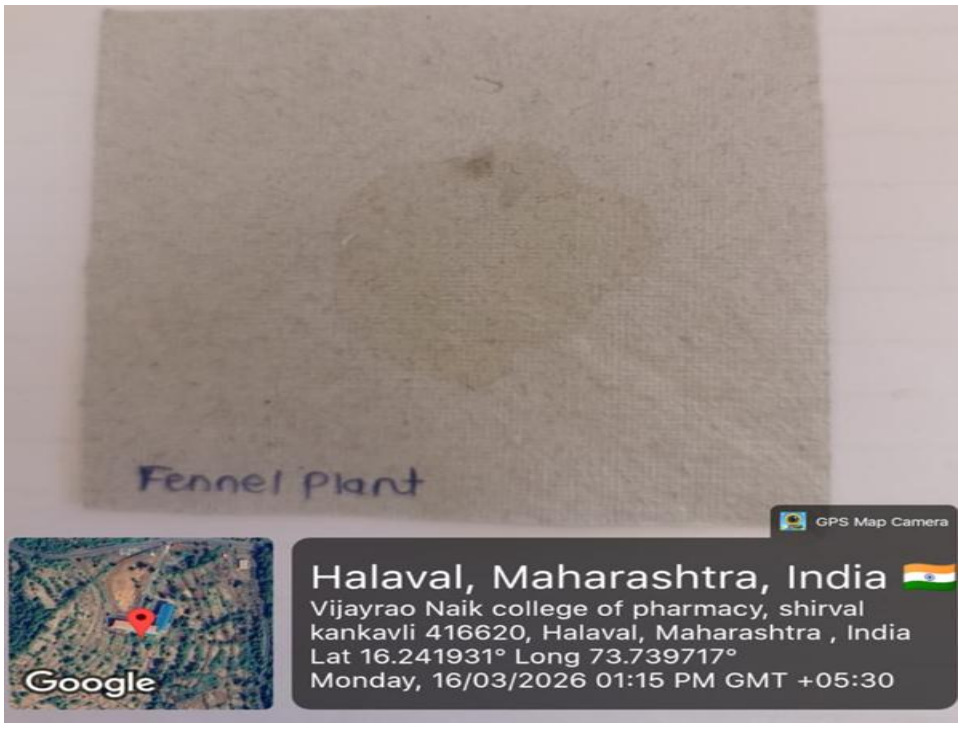
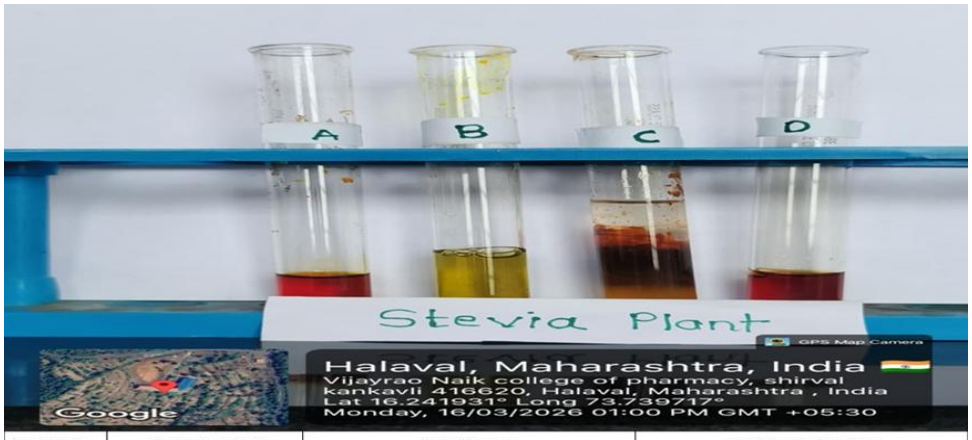


Figure 7: *Preliminary Phytochemical Screening (volatile oil) of Fennel plant*



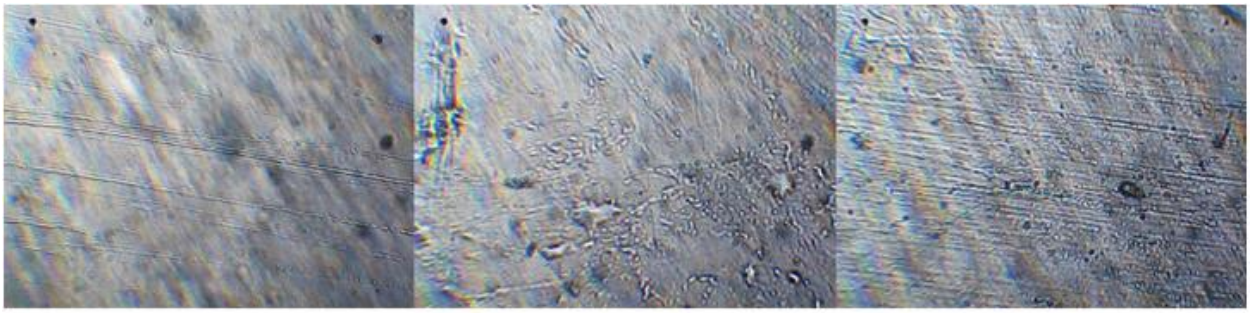
Test Tube	Phytochemical	Test Name	Positive Indication
A	Alkaloids	Dragendorff's Test	Orange or reddish-brown precipitate
B	Flavonoids	Ferric Chloride Test	Dark green, blue, or black coloration
C	Glycosides	Modified Borntrager's Test	Pink to red coloration in ammoniacal layer
D	Phenolic Compounds	Iodine Test	Blue or dark coloration

Figure 8. Preliminary Phytochemical Screening of stevia plant:

The phytochemical screening indicated the presence of several biologically active constituents including flavonoids, phenolic compounds, glycosides, and terpenoids, which are known to contribute to antioxidant and metabolic regulatory activities. The volatile oil test confirmed the presence of essential oil constituents in Foeniculum vulgare, while Stevia rebaudiana extract showed the presence of glycosides responsible for its natural sweetening property.

Digital Microscopic evaluation of herbal extracts:

The digital microscopic images of Costus igneus, Foeniculum vulgare, and Stevia rebaudiana extracts revealed a well-obtained and uniform preparation with clear cellular structures and no visible contamination. The observations confirmed the consistency, integrity, and quality of the extracts, ensuring their suitability for formulation and further pharmacological evaluation.



Sample 1. Insulin plant **Sample 2. Fennel plant** **Sample 3. Stevia plant**

Figure 9: *Digital Microscopic evaluation of herbal extracts*

Preparation of antidiabetic herbal syrup:

Ingredient (30 mL)	F1 (gm & ml)	F2 (gm & ml)	F3 (gm & ml)	F4 (gm & ml)	F5 (gm & ml)	F6 (gm & ml)	F7 (gm & ml)
Costus igneus extract (3%)	0.9 (ml)	0.9 (ml)	0.9 (ml)	0.9 (ml)	0.9 (ml)	0.9 (ml)	0.9 (ml)
Foeniculum vulgare extract (3%)	0.9 (ml)	0.9 (ml)	0.9 (ml)	0.9 (ml)	0.9 (ml)	0.9 (ml)	0.9 (ml)
Stevia rebaudiana extract (7%)	2.1 (ml)	2.1 (ml)	2.1 (ml)	2.1 (ml)	2.1 (ml)	2.1 (ml)	2.1 (ml)
Aloe vera gel	0.30	0.60	0.60	0.90	0.90	1.20	1.20
Acacia gum	0.30	0.35	0.40	0.45	0.50	0.55	0.60
Treagacanth gum	0.30	0.35	0.40	0.45	0.50	0.55	0.60
Citric acid	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Sodium benzoate	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Ascorbic acid	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Natural flavouring agent (Fennel + Lemon oil blend)	0.09 (ml)	0.09 (ml)	0.09 (ml)	0.09 (ml)	0.09 (ml)	0.09 (ml)	0.09 (ml)
Purified water	q.s. to 30 mL	q.s. to 30 mL	q.s. to 30 mL	q.s. to 30 mL	q.s. to 30 mL	q.s. to 30 mL	q.s. to 30 mL

The anti-diabetic polyherbal syrup was prepared by the following steps

Table 4: *Formulation of poly-herbal syrup [30 ml]*

Step 1: Preparation of Extract Paste:

Accurately weighed quantities of concentrated extracts of Costus igneus, Foeniculum vulgare, and Stevia rebaudiana were triturated with a small quantity of purified water to obtain a smooth, uniform paste to facilitate proper dispersion in the formulation.

Step 2: Preparation of Syrup Base:

The syrup base was prepared by dispersing the required quantity of acacia gum in a measured volume of purified water under continuous stirring to obtain a uniform mucilaginous solution. Aloe vera gel was incorporated gradually with constant stirring to enhance viscosity and improve the consistency of the formulation.

The calculated quantity of Stevia rebaudiana extract was then added as the sweetening component and mixed thoroughly to ensure uniform distribution. Citric acid, previously dissolved in a small quantity of purified water, was incorporated to adjust the pH of the formulation. Sodium benzoate was added as a preservative, followed by ascorbic acid as an antioxidant to prevent oxidative degradation of phytoconstituents. Stirring was continued until a homogeneous syrup base was obtained.

Step 3: Incorporation of Extract Paste:

The prepared extract paste was gradually incorporated into the syrup base with continuous stirring to ensure uniform dispersion and prevent aggregation.

Step 4: Volume Adjustment:

The final volume of the formulation was adjusted to 30 mL using purified water, and the mixture was stirred until homogeneous and viscous syrup was formed.

Step 5: Storage:

The formulation was transferred into sterilized amber-coloured glass bottles, properly labelled, and stored at room temperature for further evaluation.

Evaluation Parameter 24,25

Physicochemical Evaluation of Polyherbal Syrup Formulations

The prepared polyherbal syrup formulations (F1-F7) were evaluated for various physicochemical parameters in order to assess their quality, consistency, and suitability for oral administration. The evaluation was performed using standard pharmaceutics procedures.

1. Organoleptic Evaluation

Each formulation was visually examined for organoleptic characteristics including colour, odour, taste, clarity, and overall appearance. A

small quantity of the syrup was placed in a transparent container and observed against a white background under adequate lighting conditions to detect any turbidity or particulate matter. The odour was assessed by gentle inhalation, and the taste was evaluated in minimal quantity to determine the palatability of the formulation.

2. Determination of pH

The pH of the syrup formulations was determined using a calibrated digital pH meter. A measured quantity of the syrup sample was diluted with distilled water and thoroughly mixed. The electrode of the pH meter was immersed into the solution and the pH value was recorded at room temperature. The measurement was performed in triplicate and the average value was reported.

Figure 10: pH evaluation of herbal syrup formulation (F4)

Determination of Viscosity:

The viscosity of each formulation was determined using an Ostwald viscometer. The viscometer was cleaned and fixed vertically on a stand. Initially, distilled water was allowed to flow between two marked points and the flow time was recorded. The same procedure was repeated with the syrup sample. The viscosity of the formulation was calculated by comparing the flow time and density of the sample with that of water.

Figure 11: *Viscosity evaluation of herbal syrup formulation (F4)*

4. Determination of Specific Gravity

Specific gravity of the prepared syrup formulations was determined using a pycnometer (specific gravity bottle). The clean and dry pycnometer was first weighed empty and then filled with distilled water to determine its capacity. The same bottle was subsequently filled with the syrup sample and weighed again. The specific gravity was calculated by comparing the weight of the syrup with the weight of an equal volume of water at the same temperature.

Figure 12: *Specific gravity & Density evaluation of herbal syrup formulation (F4)*

Determination of Density:

The density of the syrup was determined using a specific gravity bottle method. The weight of the empty bottle was recorded, followed by the weight of the bottle filled with the syrup formulation. The density of the sample was calculated by dividing the mass of the syrup by the volume of the bottle.

Homogeneity and Turbidity:

The prepared formulations were examined visually to determine their homogeneity and absence of turbidity or phase separation. The formulations were considered acceptable if they showed uniform consistency without sedimentation.

Parameter	F1	F2	F3	F4	F5	F6	F7
Appearance	Light brown, clear	Light brown, clear	Br Brown, slightly viscous	Brown, slightly viscous,	Brown, slightly viscous	Brown, slightly viscous	Brown, highly viscous
Odour	Characteristic herbal	Characteristic herbal	Characteristic herbal	Characteristic herbal	Characteristic herbal	Characteristic herbal	Characteristic herbal
Taste	Sweet herbal	Sweet herbal	Sweet herbal	Sweet herbal	Sweet herbal	Sweet herbal	Sweet herbal
pH	4.78 ±0.02	4.84 ±0.03	4.89 ±0.02	4.92 ±0.02	4.94 ±0.02	4.95 ±0.02	4.97 ±0.02
Viscosity (cP)	12.67	13.73	14.10	14.95	15.12	15.45	15.61
Specific Gravity	1.056	1.065	1.066	1.067	1.076	1.079	1.081
Homogeneity	Good	Good	Good	Excellent	Excellent	Good	Good
Turbidity	Absent	Absent	Absent	Absent	Slight	Slight	Slight
Sedimentation	None	None	None	None	None	Trace	Trace

Table 5: *Physicochemical Evaluation of Polyherbal Syrup Formulations (F1-F7)*

Digital Microscopic evaluation of polyherbal anti-diabetic syrup :

The digital microscopic image shows a uniformly dispersed system containing irregular, plant-derived particles with granular and fibrous morphology. The background appears slightly turbid, indicating a mixture of dissolved and suspended components. No significant

aggregation is observed, confirming good homogeneity. Occasional air bubbles are visible as clear, spherical structures. No microbial contamination is evident, suggesting acceptable quality of the herbal syrup.

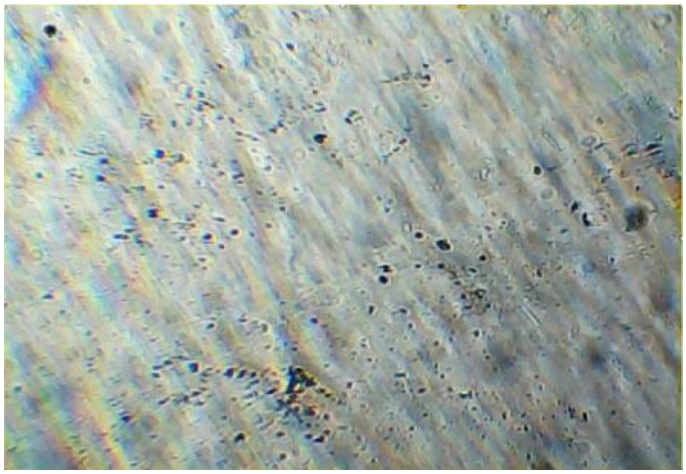


Figure 13: Digital Microscopic evaluation of polyherbal syrup formulation (F4)

Stability Study of Optimized Polyherbal Syrup (F4) 26:

The stability of the optimized formulation (F4) was evaluated under different temperature conditions including refrigerated temperature (4 °C), room temperature (25 ± 2 °C), and elevated temperature (47 °C) for a period of 72 hours. The samples were examined at 24, 48, and 72 hours for changes in physicochemical parameters such as colour, odour, taste, pH, weight per millilitre, specific gravity, and turbidity/homogeneity.

Sample Code	Time Duration (h)	Temperature (°C)	Colour	Odour	Taste	pH	Specific Gravity	Turbidity / Homogeneity
F4A	24	4°C	NC	NC	NC	4.92	1.068	No Turbidity
F4B	24	25°C	NC	NC	NC	4.91	1.069	No change
F4C	24	47°C	NC	NC	NC	4.92	1.069	Homogeneity
F4D	48	4°C	NC	NC	NC	4.91	1.068	No Turbidity
F4E	48	25°C	NC	NC	NC	4.92	1.069	No change
F4F	48	47°C	NC	NC	NC	4.91	1.068	Homogeneity
F4G	72	4°C	NC	NC	NC	4.92	1.069	No Turbidity
F4H	72	25°C	NC	NC	NC	4.92	1.069	No change
F4I	72	47°C	NC	NC	NC	4.91	1.068	Homogeneity

Table 6: *Stability Studies through Physicochemical Parameters of Optimized Polyherbal Syrup (F4)*

Figure 14: *Stability Studies through Physicochemical Parameters of Optimized Polyherbal Syrup (F4)*

Figure 15: *Solubility Studies of Optimized Polyherbal Syrup (F4) through Hydrochloric acid buffer*

The solubility study of the optimized polyherbal syrup formulation (F4) was carried out using the flask method under controlled laboratory conditions. Hydrochloric acid (HCl) buffer of pH 1.2 was prepared to simulate the acidic environment of the gastric medium. A total volume of 500 mL of the buffer solution was transferred into a clean, dry conical flask. An accurately measured 10 mL sample of the polyherbal syrup formulation (F4) was added to the prepared HCl buffer. The mixture was subjected to continuous stirring using a magnetic stirrer at a constant speed (approximately 100-150 rpm) and maintained at a controlled temperature of 37 ± 0.5°C to mimic physiological conditions. The stirring process was continued for duration of 1 hour to ensure maximum interaction between the formulation and the solvent. After completion of the stirring period, the solution was visually inspected for clarity, homogeneity, and the presence of any undissolved particles. The degree of solubility was assessed based on the formation of a clear and uniform solution without precipitation or turbidity.

This study provides insight into the solubility behaviour of the optimized formulation under acidic conditions, indicating its suitability for oral administration and its potential performance in the gastric environment.

Results and Discussion:

Preliminary phytochemical screening of the extracts of Costus igneus, Foeniculum vulgare, and Stevia rebaudiana revealed the presence of important bioactive constituents such as flavonoids, phenolic compounds, glycosides, and terpenoids. These phytoconstituents are widely reported to possess antioxidant and antidiabetic activities, supporting the therapeutic relevance of the selected plants in the development of the polyherbal formulation. In addition, the characteristic aroma of Foeniculum vulgare indicated the presence of volatile oil components, which may contribute to the overall pharmacological and sensory properties of the formulation.

Seven different formulations (F1-F7) of the polyherbal syrup were prepared by varying the concentrations of acacia gum and aloe vera gel, while maintaining constant quantities of the plant extracts. The prepared formulations exhibited clear appearance, characteristic herbal odour, and pleasant sweet taste, mainly due to the presence of Stevia rebaudiana extract acting as a natural sweetening agent.

Physicochemical evaluation showed that the pH of the formulations ranged from 4.5 to 4.9, indicating a mildly acidic nature suitable for oral liquid preparations and favourable for preservative activity. The viscosity of the formulations increased gradually from F1 to F7, which can be attributed to the increasing concentration of acacia gum and aloe vera gel acting as viscosity enhancing agents. The specific gravity values indicated appropriate density and consistency of the syrup. Among all the formulations, F4 demonstrated optimal physicochemical characteristics, including suitable viscosity, acceptable pH, and good homogeneity without turbidity or sedimentation.

The optimized formulation (F4) was further subjected to stability testing at 4 °C, 25 ± 2 °C, and 47 °C for a period of 72 hours. The formulation was evaluated at 24, 48, and 72 hours for changes in colour, odour, taste, pH, weight per millilitre, specific gravity, and turbidity. The results indicated no significant change in the physicochemical properties during the study period, suggesting that the optimized polyherbal syrup formulation remained physically stable under the tested storage conditions.

Conclusion:

The present study successfully developed polyherbal antidiabetic syrup by incorporating extracts of Costus igneus (commonly known as the insulin plant), Foeniculum vulgare (fennel), and Stevia rebaudiana. The selection of these plants was based on their complementary pharmacological properties and potential synergistic effects in glycaemic control. Costus igneus is widely recognized for its antidiabetic activity, primarily attributed to its ability to enhance insulin secretion, promote peripheral glucose uptake, and possibly support pancreatic

β-cell regeneration. Foeniculum vulgare, traditionally used as a digestive aid, contains bioactive compounds such as flavonoids and phenolics that exhibit antioxidant activity and may contribute to improved glucose metabolism by reducing oxidative stress and enhancing insulin sensitivity. Additionally, its carminative and digestive properties may support better gastrointestinal function, indirectly benefiting metabolic regulation. Stevia rebaudiana was incorporated not only for its natural sweetening property but also due to its zero-calorie profile and reported antihyperglycaemic effects, including improved insulin signaling and reduced postprandial glucose levels. The combination of these medicinal plants in a single formulation provides a multi-targeted therapeutic approach, where their individual mechanisms collectively contribute to improved glycaemic control, antioxidant defense, and digestive support. This synergistic interaction highlights the advantage of polyherbal formulations over single-drug therapies in managing complex metabolic disorders like diabetes mellitus. A total of seven formulations were developed by varying excipient concentrations and were systematically evaluated for physicochemical parameters. Among these, formulation F4 was identified as the optimized batch, exhibiting desirable pH, appropriate viscosity, uniform homogeneity, and acceptable organoleptic properties. Stability studies conducted under varying temperature conditions demonstrated no significant changes in these parameters, confirming the formulation's satisfactory short-term stability. Furthermore, the syrup dosage form offers significant patient-centric advantages, particularly for individuals with dysphagia, as well as pediatric and geriatric populations who may have difficulty swallowing solid dosage forms. The use of Stevia rebaudiana enhances patient compliance by providing sweetness without caloric load, making the formulation especially suitable for long-term use in diabetic patients. In conclusion, the study establishes the feasibility of formulating stable, palatable, and pharmaceutically acceptable polyherbal antidiabetic syrup with potential therapeutic benefits. The formulation represents a promising natural adjunct for glycaemic management through its synergistic and multi-mechanistic action. However, comprehensive pharmacological evaluations, toxicity profiling, and controlled clinical studies are essential to further substantiate its efficacy, safety, and therapeutic applicability in clinical practice.

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Conflict of interest:

None

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Ethics statement:

None

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