

Formulation And Characterization of Polyherbal Antidiabetic Nanoemulsion

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Abstract:

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia and associated long-term complications. Although synthetic antidiabetic drugs are effective, their prolonged use may lead to adverse effects, high cost, and reduced patient compliance, necessitating the development of safer and more effective alternatives. Medicinal plants with proven antidiabetic activity offer a promising approach; however, their therapeutic potential is often limited by poor solubility, low stability, and inadequate oral bioavailability. The present study aimed to formulate and characterize a polyherbal antidiabetic nanoemulsion to enhance the physicochemical properties and release profile of selected herbal extracts.

Hydroalcoholic extracts of *Momordica charantia*, *Gymnema sylvestre*, *Trigonella foenum-graecum*, and *Syzygium cumini* were combined to prepare a polyherbal extract blend. Nanoemulsions were formulated using suitable oils, surfactants, and co-surfactants, selected based on solubility studies and pseudo-ternary phase diagrams. The prepared formulations were evaluated for visual appearance, droplet size, polydispersity index, zeta potential, pH, viscosity, thermodynamic stability, and in-vitro drug release behavior. The optimized formulation exhibited nanosized droplets with narrow size distribution, high negative zeta potential indicating good stability, suitable pH, and satisfactory viscosity. Thermodynamic stability studies confirmed the robustness of the nanoemulsion system. In-vitro drug release studies demonstrated a sustained and controlled release pattern, suggesting improved availability of herbal bioactive constituents.

The developed polyherbal antidiabetic nanoemulsion effectively addressed the limitations of conventional herbal formulations and shows potential as a stable and efficient delivery system for diabetes management. Further in-vivo and clinical investigations are warranted to establish its therapeutic efficacy.

Keywords: Diabetes mellitus; Polyherbal formulation; Nanoemulsion; Antidiabetic activity; Herbal drug delivery; Droplet size; In-vitro release.

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INTRODUCTION

Diabetes mellitus is a long-term metabolic disorder marked by elevated blood glucose levels caused by

inadequate insulin secretion, reduced insulin sensitivity, or both. The increasing incidence of diabetes has become a major public health concern due to its association with

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complications such as cardiovascular disorders, kidney failure, nerve damage, and vision impairment. Although synthetic antidiabetic drugs are effective, their prolonged use may result in side effects, drug resistance, and high treatment costs, highlighting the need for safer therapeutic alternatives¹⁻².

Medicinal plants have been widely used in traditional systems of medicine for the management of diabetes owing to their natural origin, affordability, and multiple mechanisms of action. Plants such as *Momordicacharantia* (bitter gourd), *Gymnemasylvestre* (gurmar), *Trigonellafoenum-graecum* (fenugreek), and *Syzygiumcumini* (jamun) have shown significant antidiabetic potential through enhancement of insulin secretion, inhibition of glucose absorption, and antioxidant activity. Combining these herbs in a polyherbal formulation may produce synergistic effects and improved therapeutic efficacy compared to single-herb preparations³⁻⁴.

However, many herbal bioactive compounds suffer from poor water solubility, low stability, and limited bioavailability when administered orally. These limitations reduce their clinical effectiveness. Nanotechnology-based drug delivery systems have emerged as a promising approach to overcome these challenges⁵⁻⁶.

Nanoemulsions are fine oil-in-water or water-in-oil dispersions with droplet sizes in the nanometer range. Due to their small droplet size and high surface area, nanoemulsions enhance the solubility, absorption, and stability of bioactive compounds. Incorporating polyherbal extracts into a nanoemulsion system can improve oral bioavailability and therapeutic performance⁷⁻⁸.

Therefore, the present study aims to formulate and characterize a polyherbal antidiabetic nanoemulsion containing selected medicinal plant extracts to enhance their physicochemical properties, stability, and antidiabetic potential⁹⁻¹⁰.

MATERIALS AND METHODS

Materials

The plant materials *Momordicacharantia* fruits, *Gymnemasylvestre* leaves, *Trigonellafoenum-graecum* seeds, and *Syzygiumcumini* seeds were procured from a certified herbal supplier. The plants were authenticated by a botanist, and voucher specimens were preserved for reference.

All chemicals, solvents, oils, surfactants, and co-surfactants used in the study were of analytical grade. Distilled water was used throughout the experimental work.³

METHODS

1. Preparation of Plant Extracts

The collected plant materials were thoroughly washed with distilled water and shade-dried at room temperature. The dried materials were separately pulverized into coarse powder using a mechanical grinder. Each powdered plant material was extracted using hydroalcoholic solvent by maceration for an appropriate duration with occasional

stirring. The extracts were filtered and concentrated using a rotary evaporator. The dried extracts were stored in airtight containers until further use.⁴

2. Preparation of Polyherbal Extract Mixture

Equal quantities of the dried extracts of *Momordicacharantia*, *Gymnemasylvestre*, *Trigonellafoenum-graecum*, and *Syzygiumcumini* were accurately weighed and mixed uniformly to obtain a polyherbal extract blend.⁵

3. Solubility Study

The solubility of the polyherbal extract blend was evaluated in various oils, surfactants, and co-surfactants. Excess extract was added to each component and mixed continuously. After equilibrium, the mixtures were centrifuged and visually examined. The components showing maximum solubility were selected for nanoemulsion formulation.⁶

4. Construction of Pseudo-Ternary Phase Diagram

Pseudo-ternary phase diagrams were constructed using the water titration method. Different ratios of selected oil and surfactant-co-surfactant mixture were prepared. Distilled water was added dropwise under continuous stirring. Transparent and stable systems were identified as nanoemulsion regions.⁷

5. Preparation of Polyherbal Nanoemulsion

The polyherbal extract mixture was dissolved in the selected oil phase. The surfactant and co-surfactant mixture was then added and stirred gently. Distilled water was gradually incorporated under continuous stirring to obtain a homogeneous nanoemulsion. The formulation was further homogenized to achieve uniform droplet size.⁸

6. Characterization of Nanoemulsion

Droplet Size and Polydispersity Index: Determined using a particle size analyzer after suitable dilution.

Zeta Potential: Measured to evaluate surface charge and stability.

pH Measurement: Determined using a calibrated digital pH meter.

Viscosity: Measured using a viscometer at room temperature.

Thermodynamic Stability: Assessed through heating-cooling cycles, centrifugation, and freeze-thaw studies.^{9,10}

Result:

Table 1: Composition of Polyherbal Antidiabetic Nanoemulsion Formulations

Formula Code	Oil Phase (% w/w)	Surfactant (% w/w)	Co-Surfactant (% w/w)	Aqueous Phase (% w/w)	Polyherbal Extract (mg)
F1	10	30	10	50	100
F2	12	28	10	50	100
F3	15	25	10	50	100
F4	18	22	10	50	100
F5	20	20	10	50	100

Table 2: Visual Appearance and Physical Stability of Formulations

Formulation Code	Appearance	Phase Separation	Transparency	Stability
F1	Clear	Absent	High	Stable
F2	Clear	Absent	High	Stable
F3	Slightly opalescent	Absent	Moderate	Stable
F4	Turbid	Present	Low	Unstable
F5	Turbid	Present	Low	Unstable

Table 3: Droplet Size and Polydispersity Index (PDI)

Formulation Code	Mean Droplet Size (nm)	Polydispersity Index
F1	82.4 ± 2.1	0.218 ± 0.01
F2	95.6 ± 1.8	0.236 ± 0.02
F3	118.3 ± 2.5	0.289 ± 0.02
F4	165.7 ± 3.2	0.356 ± 0.03
F5	198.4 ± 3.8	0.412 ± 0.04

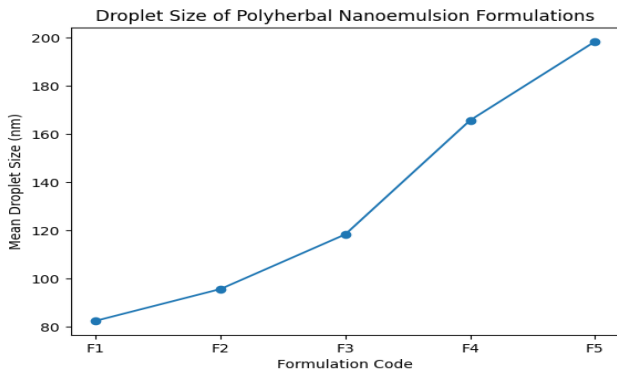


Figure 1: Droplet Size of Polyherbal Antidiabetic Nanoemulsion Formulations

Table 4: Zeta Potential of Nanoemulsion Formulations

Formulation Code	Zeta Potential (mV)	Interpretation
F1	-32.5 ± 1.4	Highly stable
F2	-30.2 ± 1.6	Stable
F3	-27.8 ± 1.3	Moderately stable

F4	-22.4 ± 1.9	Less stable
F5	-18.6 ± 2.1	Unstable

Table 5: pH and Viscosity of Nanoemulsion Formulations

Formulation Code	pH	Viscosity (cP)
F1	6.5 ± 0.1	92 ± 3
F2	6.6 ± 0.1	98 ± 4
F3	6.7 ± 0.2	105 ± 5
F4	6.8 ± 0.2	118 ± 6
F5	6.9 ± 0.2	130 ± 7

Table 6: Thermodynamic Stability Study Results

Formulation Code	Heating-Cooling Cycle	Centrifugation Test	Freeze-Thaw Cycle
F1	Passed	Passed	Passed
F2	Passed	Passed	Passed
F3	Passed	Passed	Passed
F4	Failed	Failed	Failed
F5	Failed	Failed	Failed

Table 7: In-Vitro Drug Release Study (% Cumulative Release)

Time (hrs)	F1	F2	F3	F4	F5
1	18.6	16.2	14.5	10.4	9.1
2	32.4	29.1	26.2	18.3	15.7
4	55.8	52.4	47.3	35.6	30.8
6	71.6	68.2	62.5	48.9	42.3
8	88.4	84.6	79.2	63.1	55.7

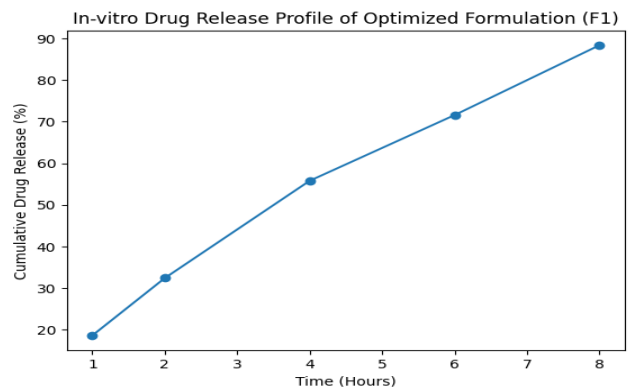


Figure 2: In-vitro Drug Release Profile of Optimized Formulation (F1)

Table 8: Selection of Optimized Formulation

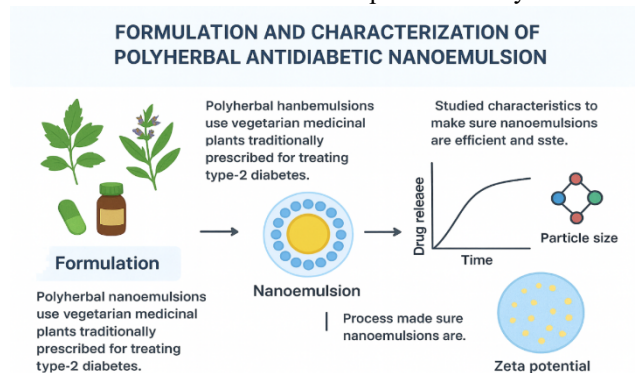
Parameter	Optimized Formulation (F1)
Droplet size	Lowest

PDI	< 0.25
Zeta potential	> -30 mV
Drug release	Highest
Stability	Excellent

CONCLUSION

In the present study, a polyherbal antidiabetic nanoemulsion was successfully formulated using selected medicinal plant extracts with proven antidiabetic potential. The developed nanoemulsion exhibited acceptable physicochemical properties, including nanosized droplet diameter, uniform distribution, suitable pH, and good stability. Among the prepared formulations, the optimized formulation showed the smallest droplet size, high zeta potential, and satisfactory thermodynamic stability, indicating a stable nanoemulsion system.

The in vitro drug release study demonstrated a sustained and controlled release pattern, which may enhance the bioavailability of herbal bioactive compounds. The nanoemulsion approach effectively addressed the limitations associated with conventional herbal formulations, such as poor solubility and low absorption. Overall, the formulated polyherbal antidiabetic nanoemulsion shows promising potential as an effective and safe delivery system for the management of diabetes mellitus. Further in vivo and clinical studies are recommended to confirm its therapeutic efficacy.



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