World Journal of Pharmaceutical Science and Research
www.wjpsronline.com
Research Article
ISSN: 2583-6579
SJIF Impact Factor: 6.916
Year - 2026
Volume: 5; Issue: 4
Page: 632-653

TO FORMULATE AND EVALUATE A TOPICAL EMULGEL CONTAINING *NYCTANTHES ARBOR-TRISTIS* (*HARSINGAR*) EXTRACT AND β-SITOSTEROL FOR THE MANAGEMENT OF GOUT-ASSOCIATED INFLAMMATION

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Article Received: 26 February 2026 | | ***Article Revised: 19 March 2026*** | | ***Article Accepted: 8 April 2026***

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DOI: https://doi.org/10.5281/zenodo.19593425

How to cite this Article: Shadab Mobeen, Dr. Bandana Singh, Dr. Karuna Shanker Shukla, Shalini Singh (2026) TO FORMULATE AND EVALUATE A TOPICAL EMULGEL CONTAINING *NYCTANTHES ARBOR-TRISTIS (HARSINGAR)* EXTRACT AND β-SITOSTEROL FOR THE MANAGEMENT OF GOUT-ASSOCIATED INFLAMMATION. World Journal of Pharmaceutical Science and Research, 5(4), 632-653

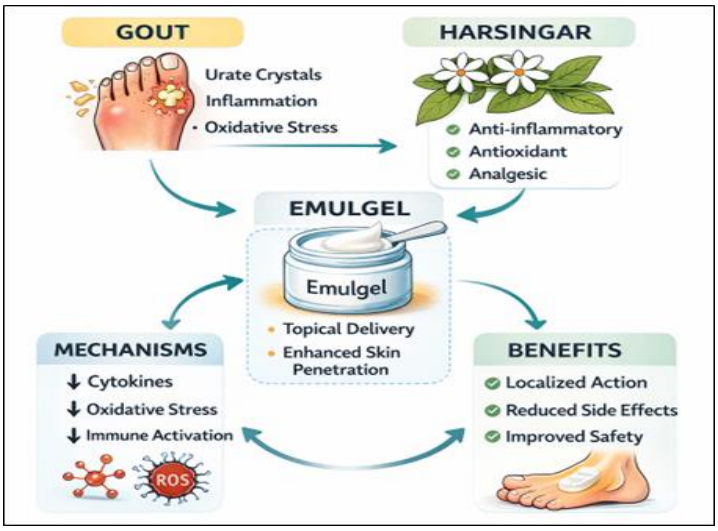
ABSTRACT

Gout is a chronic inflammatory disorder characterized by recurrent acute flares resulting from monosodium urate crystal deposition, activation of innate immune pathways, and excessive oxidative stress within affected joints. Although conventional pharmacological therapies such as non-steroidal anti-inflammatory drugs, colchicine, and urate-lowering agents remain the mainstay of treatment, their long-term clinical use is frequently limited by systemic adverse effects, poor patient adherence, and safety concerns, particularly in elderly patients with comorbidities. In this context, plant-based therapeutics combined with advanced topical drug delivery systems offer a promising alternative strategy for localized and safer management of gouty inflammation. *Nyctanthes arbor-tristis* (Harsingar), a medicinal plant widely used in traditional medicine, possesses well-documented anti-inflammatory, antioxidant, analgesic, and immunomodulatory properties attributable to its rich content of iridoid glycosides, flavonoids, and phenolic compounds. This review critically examines the pathophysiology of gout and systematically correlates it with the pharmacological activities of Harsingar, emphasizing its ability to modulate key inflammatory mediators, oxidative stress pathways, and immune cell activation involved in gout progression. Furthermore, the potential of emulgel-based topical delivery systems for improving the stability, skin permeation, and localized bioavailability of Harsingar phytoconstituents is discussed in detail. By integrating ethnopharmacological evidence, mechanistic insights, and formulation strategies, this review highlights Harsingar-based emulgels as a novel, multi-targeted, and patient-friendly therapeutic approach for gout management, while also identifying current research gaps and future directions for clinical translation.

KEYWORDS: Gout, *Nyctanthes arbor-tristis*, Harsingar, Topical emulgel, Anti-inflammatory activity, Antioxidant activity, Plant-based therapeutics.

Graphical Abstract

Schematic representation of gout pathophysiology and the proposed therapeutic role of a *Nyctanthes arbor-tristis* (Harsingar) based topical emulgel, highlighting localized multi-target anti-inflammatory action with reduced systemic toxicity.



1. INTRODUCTION

Gout is a chronic metabolic and inflammatory disorder characterized by recurrent episodes of acute joint pain, swelling, erythema, and functional impairment. The disease primarily results from sustained hyperuricemia, which promotes the crystallization and deposition of monosodium urate crystals in synovial joints and periarticular tissues.[1] These crystals act as potent inflammatory stimuli, triggering innate immune responses that involve activation of the NLRP3 inflammasome and subsequent release of pro-inflammatory mediators such as interleukin-1β, tumor necrosis factor-α, and interleukin-6. Persistent inflammation not only exacerbates joint damage but also significantly reduces quality of life in affected individuals.[2] The rising global prevalence of gout, driven by dietary habits, sedentary lifestyles, aging populations, and metabolic comorbidities, highlights the urgent need for effective and safer therapeutic interventions.

Conventional pharmacological management of gout relies largely on non-steroidal anti-inflammatory drugs, colchicine, corticosteroids, and urate-lowering agents such as allopurinol and febuxostat.[3] While these therapies are effective in controlling acute attacks and reducing serum uric acid levels, their long-term use is often limited by adverse effects and clinical contraindications. NSAIDs are associated with gastrointestinal irritation, cardiovascular risks, and renal impairment, whereas colchicine may cause gastrointestinal toxicity and neuromuscular complications, particularly in elderly patients or those with compromised renal function.[4] Urate-lowering therapies require prolonged administration and careful dose monitoring, and in some cases may precipitate acute gout flares during initiation. These limitations frequently result in poor patient adherence and underscore the need for alternative therapeutic strategies that can provide symptomatic relief with reduced systemic burden.[5]

In recent years, there has been growing scientific interest in plant-based therapeutics owing to their structural diversity, multi-targeted mechanisms of action, and relatively favorable safety profiles. Medicinal plants have long been used in traditional systems of medicine for the treatment of inflammatory and arthritic disorders, and modern research has begun to validate many of these traditional claims through pharmacological and mechanistic studies.[6] Alongside this renewed focus on herbal medicines, topical drug delivery systems have gained considerable attention as an effective

approach for managing localized inflammatory conditions. Topical formulations offer the advantage of delivering active compounds directly to the site of inflammation, thereby minimizing systemic exposure and reducing the risk of adverse effects. Among various topical systems, emulgels have emerged as a promising platform due to their improved stability, ease of application, enhanced patient acceptability, and ability to incorporate both hydrophilic and lipophilic bioactive compounds.[7]

Nyctanthes arbor-tristis, commonly known as Harsingar or night-flowering jasmine, is a medicinal plant widely recognized in Ayurvedic and traditional medicine for its anti-inflammatory, analgesic, and antioxidant properties. The leaves of the plant are particularly rich in iridoid glycosides, flavonoids, phenolic compounds, and other bioactive constituents that have demonstrated significant pharmacological activity in experimental models of inflammation and arthritis.[8] Traditional use of Harsingar in joint pain, fever, and rheumatic conditions provides a strong ethnopharmacological basis for its selection as a potential therapeutic agent in gouty inflammation. Moreover, the plant's ability to modulate inflammatory mediators and oxidative stress pathways aligns well with the underlying pathophysiology of gout. Despite its therapeutic potential, the clinical application of *Nyctanthes arbor-tristis* remains limited due to challenges associated with the delivery and bioavailability of its phytoconstituents.[9,10] Conventional oral administration of herbal extracts often results in poor absorption, rapid metabolism, and inconsistent therapeutic outcomes. In this context, incorporating Harsingar extracts into advanced topical delivery systems such as emulgels represents a rational and innovative approach to enhance local drug concentration, improve skin permeation, and achieve sustained anti-inflammatory effects at the affected site.[11]

Table 1 provides a comparative perspective between conventional systemic gout therapies and the proposed Harsingar (*Nyctanthes arbor-tristis*)-based topical emulgel, underscoring key differences in therapeutic approach, safety profile, and mechanism of action. Conventional agents such as NSAIDs, colchicine, and urate-lowering drugs primarily exert systemic effects and are associated with gastrointestinal, renal, and cardiovascular adverse outcomes, which often limit their long-term use and patient adherence.[12] In contrast, the topical emulgel strategy offers localized delivery of bioactive phytoconstituents directly to the inflamed joint, thereby minimizing systemic exposure while maintaining effective anti-inflammatory and analgesic action. Notably, unlike standard therapies that act on single molecular targets, the Harsingar emulgel demonstrates a multi-target pharmacological profile, integrating anti-inflammatory, antioxidant, analgesic, and immunomodulatory effects that align closely with the multifactorial pathophysiology of gout.[13] The absence of flare induction during treatment initiation and the reduced requirement for laboratory monitoring further support its suitability for chronic and elderly patients. Collectively, this comparison highlights the potential of Harsingar-based emulgels as a safer and patient-friendly adjunct or alternative to conventional gout management strategies.[14]

Table 1: Comparative overview of conventional systemic gout therapies and the proposed Harsingar (*Nyctanthes arbor-tristis*)-based topical emulgel, highlighting differences in route of administration, therapeutic targets, safety profile, and multi-target anti-inflammatory potential.

S.No	Parameter	NSAIDs/Colchicine	Urate-Lowering Drugs	Harsingar Emulgel	References
1	Route of administration	Oral	Oral	Topical	15
2	Primary therapeutic goal	Acute inflammation control	Serum uric acid reduction	Local inflammation and pain control	16
3	Main biological target	COX enzymes/microtubules	Xanthine oxidase	Inflammatory mediators + ROS	17
4	Site of action	Systemic	Systemic	Localized (affected joint)	18
5	Effect on hyperuricemia	No	Yes	Indirect/supportive	19
6	Anti-inflammatory action	Strong	Indirect	Strong (multi-pathway)	20
7	Antioxidant activity	Minimal	None	High	21
8	Analgesic potential	High	Low	Moderate-High	22
9	Immunomodulatory effect	Non-selective	None	Balanced immune modulation	23
10	Risk of GI toxicity	High	Moderate	Very low	24
11	Renal safety concerns	Significant	Significant	Minimal	25
12	Cardiovascular risk	Present	Reported	Negligible	26
13	Risk of acute flare on initiation	No	Yes	No	27
14	Suitability for elderly patients	Limited	Cautious use	Highly suitable	28
15	Drug-drug interaction risk	High	Moderate	Low	29
16	Long-term use feasibility	Poor	Moderate	Good	30
17	Patient compliance	Low	Moderate	High	31
18	Need for laboratory monitoring	Frequent	Essential	Not required	32
19	Overall safety-efficacy balance	Moderate	Moderate	Favorable	33

2. MATERIALS AND METHODS

2.1 Research Design

This study aimed to develop and evaluate a topical emulgel of Harsingar leaf extract and β-sitosterol for gout inflammation. The leaves were collected, authenticated, processed, and extracted. Pre-formulation studies were carried out to assess properties and compatibility. Based on these results, six formulations were prepared with different polymer and emulsifier levels and evaluated for physicochemical properties, drug content, in vitro release, and stability.

2.2 Materials Used

Fresh Harsingar (Nyctanthes arbor-tristis) leaves were selected as the plant source, along with β-sitosterol as the active compound. Carbopol 934 served as the gelling agent, while liquid paraffin formed the oil phase. Span 80 and Tween 80 were used as emulsifiers. Propylene glycol acted as a co-solvent and penetration enhancer. Triethanolamine was used for pH adjustment. Methyl paraben and propyl paraben were added as preservatives. Ethanol and distilled water were used in extraction and formulation. All materials were of analytical grade.

2.3 Collection and Preparation of Plant Material

2.3.1 Collection of Plant Material

Fresh leaves of *Harsingar* were collected from a local source in sufficient quantity. Only healthy, mature, and disease-free leaves were selected for the study. The collected leaves were placed in clean polyethylene bags and transported to the laboratory for further processing.

2.3.2 Cleaning of Leaves

The collected leaves were washed first with tap water to remove dust, soil particles, and other adhering impurities. They were then rinsed with distilled water to ensure complete cleaning.

2.3.3 Drying of Plant Material

After washing, the leaves were spread uniformly on clean trays and dried under shade at room temperature for **8 days**. They were turned once daily to allow uniform drying from all sides. Drying was carried out away from direct sunlight to minimize degradation of thermolabile and photosensitive phytoconstituents.

2.3.4 Powdering and Storage

The completely dried leaves were ground with the help of a mechanical grinder to obtain a coarse powder. The powder was passed through **sieve no. 40** to achieve fairly uniform particle size. The sieved powder was stored in an airtight amber-colored glass container until used for extraction.

3. Pre-formulation Study

Pre-formulation studies were performed prior to emulgel development to evaluate the properties and suitability of the plant extract and β-sitosterol. These included identification, λmax determination, calibration curve, solubility study, partition coefficient, and FTIR compatibility analysis.

3.1 Identification of Plant Material

The plant material selected for the present study was *Harsingar* (*Nyctanthes arbor-tristis*) leaves. Proper identification was performed before extraction to confirm the authenticity of the material used.

3.4.1.1 Morphological Evaluation

Fresh leaves were visually examined for features like color, shape, texture, size, margin, apex, and odor. They appeared dark green, rough, and oppositely arranged, matching the typical characteristics of *Nyctanthes arbor-tristis* and confirming their identity.

3.4.1.2 Authentication of Plant

The collected leaves were authenticated by comparing their features with standard references and expert verification. The plant was confirmed as *Nyctanthes arbor-tristis* Linn., and the verified material was used for further studies.

3.4.2 Determination of λmax by UV–Visible Spectroscopy

The maximum absorption wavelength was determined using UV–Visible spectroscopy. A 100 µg/mL stock solution was prepared, diluted, and scanned between 200–400 nm. The wavelength with highest absorbance was noted as λmax for further analysis.

3.4.3 Preparation of Calibration Curve

A calibration curve was prepared using UV spectrophotometric analysis. A standard stock solution of **100 µg/mL** was prepared by dissolving **10 mg** of the sample in **100 mL** of solvent. From this stock solution, aliquots were withdrawn and diluted to prepare concentrations of **2, 4, 6, 8, 10, and 12 µg/mL**. The absorbance of each dilution was measured at the previously determined λmax using the same solvent as blank. A graph was plotted between concentration and

absorbance, and the regression equation was obtained. The calibration curve was later used for estimation of drug content and in vitro release samples.

3.4.4 Solubility Study

Solubility was evaluated by adding excess extract and β-sitosterol to different solvents and observing after 24 hours. The extract showed better dispersion in aqueous and hydroalcoholic media, while β-sitosterol was more soluble in propylene glycol and oily phases.

3.4.5 Determination of Partition Coefficient

The partition coefficient was determined to assess lipophilic behavior. The sample was mixed with n-octanol and water, shaken, and allowed to separate. The aqueous phase was analyzed, and the value was calculated using P = Co/Cw. This study helped evaluate the drug's suitability for topical delivery.

3.4.6 Drug–Excipient Compatibility Study by FTIR

Compatibility between the extract, β-sitosterol, and excipients was checked using FTIR. Spectra of pure drugs and their mixtures were recorded (4000–400 cm^{-1}) and compared. No major changes in characteristic peaks indicated good compatibility.

3.5 Preparation of Hydroalcoholic Extract

3.5.1 Extraction by Maceration Method

The hydroalcoholic extract of *Harsingar* leaves was prepared by the maceration method. Accurately weighed **100 g** of leaf powder was transferred into a clean glass container. To this, **1000 mL** of hydroalcoholic solvent mixture containing ethanol and water in the ratio of **70:30** was added. The container was closed properly and kept at room temperature for **72 hours**. During the extraction period, the mixture was shaken **3 to 4 times daily** to improve extraction of phytoconstituents from the powdered material.

3.5.2 Filtration and Concentration of Extract

After maceration, the mixture was filtered through muslin cloth followed by Whatman No. 1 filter paper. The filtrate was concentrated on a water bath (40–45°C) to obtain a semisolid extract, which was then stored at 4°C for further use.

3.5.3 Determination of Percentage Yield

The percentage yield of the extract was calculated by using the following formula:

$$\text{Percentage yield} = \frac{\text{Weight of dried extract}}{\text{Weight of crude plant powder}} \times 100$$

This calculation helped in assessing the extraction efficiency of the selected solvent system.

3.6 Formulation Development of Emulgel

3.6.1 Selection of Oil Phase

The oil phase was selected based on the lipophilic nature of β-sitosterol and the need for a stable emulsion. Since it showed better solubility in oily media, liquid paraffin was chosen for its compatibility and suitability for topical use. It was used in the range of 5.0–7.5 mL per 100 g of formulation.

3.6.2 Selection of Aqueous Phase

The aqueous phase was selected based on its ability to disperse the Harsingar extract. Distilled water was used for proper dispersion, hydration of Carbopol 934, and to make up the final weight of the formulation to 100 g.

3.6.3 Selection of Emulsifying Agent

Emulsifiers were selected to obtain a stable oil-in-water emulsion. Span 80 (lipophilic) and Tween 80 (hydrophilic) were used to improve stability and reduce interfacial tension. Span 80 was used in the range of 1.0–1.5 mL and Tween 80 in 0.5–1.0 mL per 100 g of formulation.

3.6.4 Preparation of Emulsion

The emulsion was prepared by separately heating the oil phase (liquid paraffin, Span 80, and β-sitosterol) and aqueous phase (Tween 80, distilled water, extract, and preservatives) to 70 ± 2°C. The oil phase was then added slowly to the aqueous phase with continuous stirring at 1500 rpm for 15 minutes to form a uniform emulsion, which was allowed to cool with gentle stirring.

3.6.5 Preparation of Gel Base

The gel base was prepared by dispersing Carbopol 934 in about 40 mL distilled water and allowing it to swell for 24 hours. Triethanolamine was then added gradually to form a clear gel, and the pH was adjusted to 6.0–6.8 for safe topical use.

3.6.6 Incorporation of Emulsion into Gel Base

The prepared emulsion was slowly mixed into the gel base with gentle stirring to ensure uniformity and prevent phase separation. Equal proportions were blended to obtain a smooth, homogeneous emulgel with minimal air entrapment.

3.6.7 Preparation of Different Formulations

Six formulations (F1–F6) were prepared by varying the amounts of Carbopol 934, liquid paraffin, Span 80, and Tween 80, while keeping Harsingar extract (2 g) and β-sitosterol (0.5 g) constant in each 100 g batch. These variations were done to study their effect on formulation properties and to select the best formulation.

3.7 Formulation Table

Table 3.1 Composition of Harsingar–β-sitosterol emulgel formulations (100 g batch).

Ingredients	F1	F2	F3	F4	F5	F6
Harsingar extract (g)	2.0	2.0	2.0	2.0	2.0	2.0
β-sitosterol (g)	0.5	0.5	0.5	0.5	0.5	0.5
Carbopol 934 (g)	0.5	1.0	1.5	0.5	1.0	1.5
Liquid paraffin (mL)	5.0	5.0	5.0	7.5	7.5	7.5
Span 80 (mL)	1.0	1.0	1.0	1.5	1.5	1.5
Tween 80 (mL)	0.5	0.5	0.5	1.0	1.0	1.0
Propylene glycol (mL)	5.0	5.0	5.0	5.0	5.0	5.0
Methyl paraben (g)	0.15	0.15	0.15	0.15	0.15	0.15
Propyl paraben (g)	0.05	0.05	0.05	0.05	0.05	0.05
Triethanolamine	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.
Distilled water	q.s. to 100 g	q.s. to 100 g	q.s. to 100 g	q.s. to 100 g	q.s. to 100 g	q.s. to 100 g

3.8 Method of Preparation of Emulgel

3.8.1 Preparation of Gel Base

Carbopol 934 was dispersed in about 40 mL distilled water with slow stirring and allowed to swell for 24 hours. Triethanolamine was then added dropwise to form a clear gel, and the pH was adjusted to 6.0–6.8 for suitable skin application.

3.8.2 Preparation of Oil Phase

he oil phase was prepared by mixing liquid paraffin and Span 80, followed by addition of β-sitosterol. The mixture was gently heated for uniform mixing and then maintained at 70 ± 2°C.

3.8.3 Preparation of Aqueous Phase

The aqueous phase was prepared by dissolving Tween 80 in distilled water, followed by addition of Harsingar extract. Preservatives were mixed after dissolving in propylene glycol. The phase was then heated to 70 ± 2°C.

3.8.4 Preparation of Emulsion

The oil phase was gradually added to the aqueous phase with continuous stirring at about 1500 rpm for 15 minutes. Stirring was continued until a uniform emulsion formed, then cooled to room temperature with gentle mixing.

3.8.5 Preparation of Emulgel

The emulsion was slowly mixed with the gel base in about 1:1 ratio with gentle stirring to obtain a smooth and uniform emulgel. The final weight was adjusted with distilled water, then the formulation was packed, labeled, and stored for further evaluation.

3.9 Evaluation of Emulgel

3.9.1 Physical Appearance and Homogeneity

All six formulations were visually checked for color, consistency, smoothness, and phase separation. A small amount was rubbed between fingers to assess uniformity. Smooth and particle-free formulations were considered homogeneous.

3.9.2 Determination of pH

The pH was measured by dispersing 1 g of emulgel in 10 mL distilled water. After 2 hours, readings were taken using a calibrated pH meter, and the average of triplicate values was recorded.

3.9.3 Determination of Viscosity

Viscosity of each emulgel was measured at 25 ± 1°C using a Brookfield viscometer. About 50 g of sample was tested, and readings were recorded after stabilization to compare flow properties of different batches.

3.9.4 Spreadability Study

Spreadability was measured using the glass slide method. 0.5 g of emulgel was placed between slides, a 500 g weight applied for 5 minutes, and the time for the upper slide to move 7.5 cm under added weight was recorded to calculate spreadability.

Spreadability was calculated by the formula:

$$S = \frac{M \times L}{T}$$

Where,

S = Spreadability, **M** = Weight tied to the upper slide (g)

L = Length moved by the slide (cm), **T** = Time taken (sec)

3.9.5 Extrudability

Extrudability was evaluated by filling the formulation into collapsible tubes. The tube was pressed manually, and the ease with which the emulgel came out from the nozzle was observed. Formulations that extruded smoothly with slight pressure were considered satisfactory.

3.9.6 Drug Content Determination

1 g of emulgel was dissolved in 100 mL solvent, stirred for 30 minutes, and filtered. The filtrate was diluted and analyzed by UV–Visible spectrophotometry at λmax, and drug content was calculated as a percentage of the theoretical value.

3.9.7 In Vitro Drug Release Study

The release study was performed using a Franz diffusion cell with a pre-soaked membrane. 1 g of emulgel was placed in the donor compartment, and phosphate buffer pH 6.8 in the receptor compartment at 37 ± 0.5°C, stirred at 50 rpm. 5 mL samples were taken at 0.5–6 h, replaced with fresh medium, and analyzed to calculate cumulative drug release.

3.10 Stability Study

Selected formulations were stored at 25 ± 2°C and 40 ± 2°C for 30 days. They were periodically checked for changes in appearance, color, odor, pH, consistency, and phase separation, and any alterations were recorded.

3.11 Statistical Analysis

All measurements were recorded in triplicate and expressed as mean ± SD. Data for pH, viscosity, spreadability, drug content, and in vitro release were compared to identify the optimized formulation.

RESULTS AND DISCUSSION

4.1 Pre-formulation Study

4.1.1 Identification of Plant Material

4.1.1.1 Morphological Evaluation

Harsingar leaves were dark green, rough, opposite, ovate with pointed apex and entire to slightly undulating margin. Their odor and surface features matched standard descriptions, confirming suitability for the study.

4.1.1.2 Authentication of Plant

The plant material was authenticated as *Nyctanthes arbor-tristis* Linn. on the basis of morphological comparison with standard botanical characters. The authenticated leaves were used for drying, powdering, extraction, and formulation development.

सी एस आई आर – राष्ट्रीय वनस्पति अनुसंधान संस्थान
(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्)
राणा प्रताप मार्ग, पोस्ट बाक्स सं0 436, लखनऊ-226 001 (भारत)
CSIR - NATIONAL BOTANICAL RESEARCH INSTITUTE
(Council of Scientifl c & Industrial Research)
Rana Pratap Marg, P.B. No. 436, Lucknow-226 001 (India)

सं0 / No. दिनांक / Date

PDSH/LWG/Authentication/2025-26/ 56 15 December 2025

Dr. K.M. Prabhukumar
Principal Scientist and Herbarium Curator (LWG)
Plant Diversity, Systematics and Herbarium Division
Email: curator-lwg.nbri@nbri.res.in

Sub.: Taxonomic authentication of sample - reg.
Ref.: Ang./2025-26/65 dated 30 October 2025

This is certified that, the sample submitted by Shadab Mobeen, M. Pharm student, Goel Institute of Pharmaceutical Sciences, Lucknow has been authenticated as follow.

Sr. No.	Botanical Name	Family
1.	*Nyctanthes arbor-tristis* L.	Oleaceae

CSIR-NBRI LWG Herbarium

15/12/2025

(Prabhukumar K.M.)

To,
1. *Shadab Mobeen, M. Pharm student, Goel Institute of Pharmaceutical Sciences, Lucknow.*

EPABX Phones : 2208531, 32, 33, 2297800-2297999
E-mail : director@nbri.res.in
Gram : BAGH, Lucknow
Fax : (0522) 2205836, 2205839
Website : www.nbri.res.in

Figure 4.1: Taxonomic authentication certificate of *Nyctanthes arbor-tristis* L. obtained from CSIR–National Botanical Research Institute (NBRI), Lucknow, confirming the botanical identity of the plant material used in the present study.

4.1.2 Determination of λmax by UV–Visible Spectroscopy

UV scanning of the sample (200–400 nm) showed maximum absorbance at 274 nm, which was used for calibration, drug content, and in vitro release studies.

4.1.3 Preparation of Calibration Curve

The calibration curve was prepared in the concentration range of **2–12 µg/mL**. The absorbance increased proportionally with concentration, showing good linearity within the selected range. The regression equation was found to be:

$$y = 0.048x + 0.006$$

with a correlation coefficient ($\mathbf{R^2}$) of **0.999**.

The high linearity indicated that the analytical method was suitable for quantitative estimation of the active constituent in the formulation.

Table 4.1 Calibration data of selected analyte

Concentration (µg/mL)	Absorbance
2	0.102
4	0.196
6	0.291
8	0.392
10	0.485
12	0.582

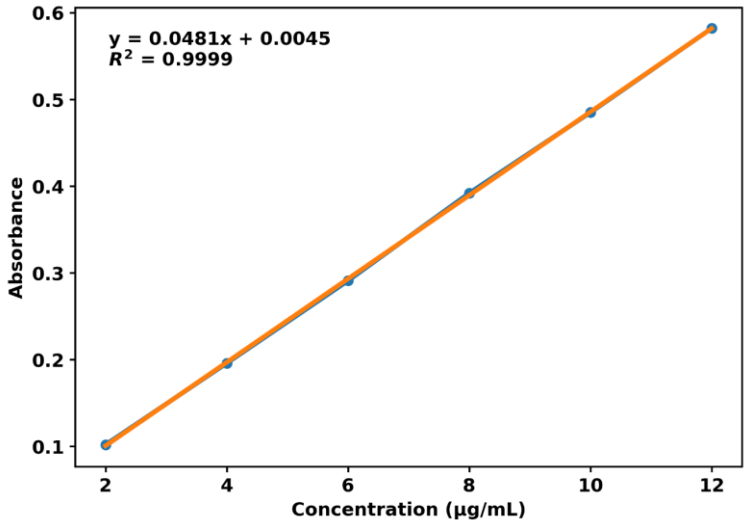


Figure 4.2: Calibration curve showing the relationship between concentration (2–12 µg/mL) and absorbance of the selected analyte, demonstrating good linearity over the studied range.

4.1.4 Solubility Study

Harsingar extract dispersed well in hydroalcoholic medium and moderately in water, while β-sitosterol was poorly water-soluble but soluble in propylene glycol and liquid paraffin, guiding their incorporation into aqueous and oil phases, respectively.

Table 4.2: Solubility profile of active constituents.

Solvent	Harsingar extract	β-sitosterol
Distilled water	Slightly soluble/dispersible	Insoluble
Ethanol	Soluble	Sparingly soluble
Methanol	Soluble	Soluble
Propylene glycol	Moderately soluble	Soluble
Liquid paraffin	Insoluble	Soluble
Phosphate buffer pH 6.8	Slightly soluble	Insoluble

4.1.5 Partition Coefficient

The partition coefficient study indicated that the selected active constituent exhibited moderate lipophilic behavior. The partition coefficient value was found to be **2.84 ± 0.09**, suggesting that the molecule possessed adequate affinity for both oily and aqueous environments, which is desirable for topical emulsion-based delivery systems.

4.1.6 Drug–Excipient Compatibility Study by FTIR

FTIR analysis showed that characteristic peaks of Harsingar extract were retained in mixtures with excipients, with only minor insignificant shifts, indicating compatibility with Carbopol 934, Tween 80, Span 80, and liquid paraffin.

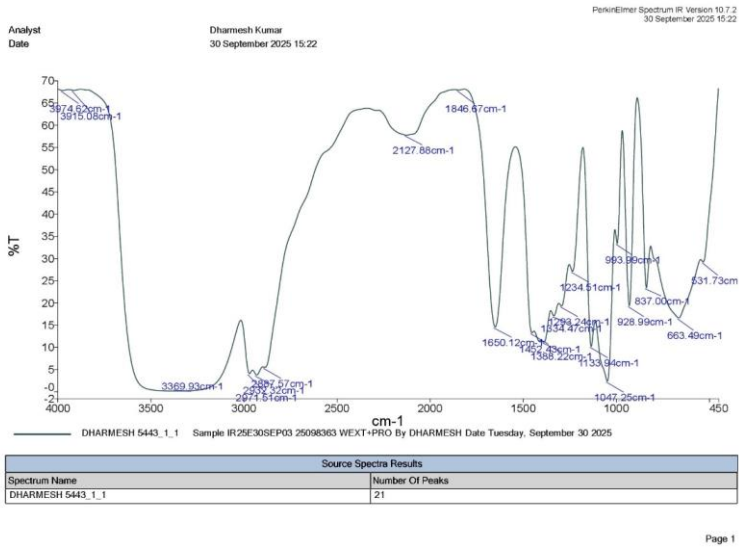


Figure 4.3: Fourier transform infrared (FTIR) spectrum of the water extract of *Nyctanthes arbor-tristis* leaves, indicating the presence of characteristic functional groups associated with the phytoconstituents of the extract.

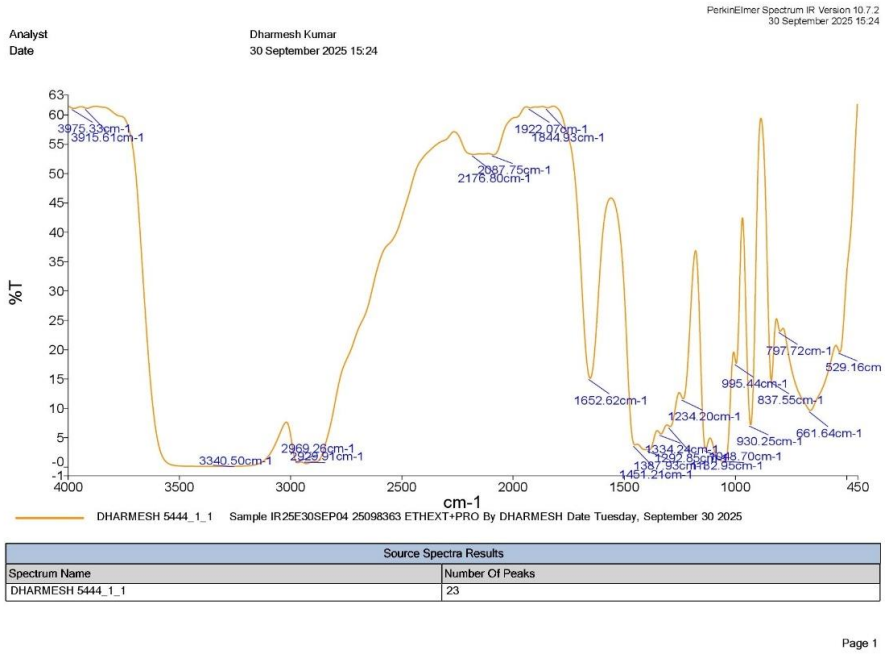


Figure 4.4: FTIR spectrum of the ethanolic extract of *Nyctanthes arbor-tristis* (*Harsingar*) leaves, showing characteristic absorption peaks corresponding to the major functional groups present in the phytoconstituents of the extract.

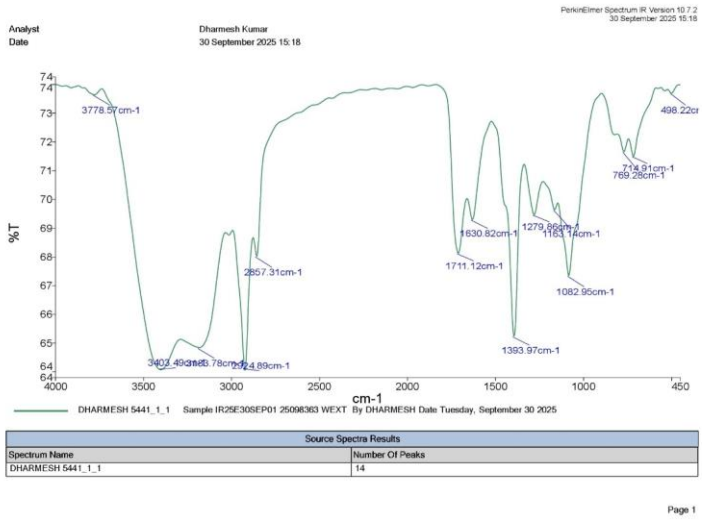


Figure 4.5: FTIR spectrum of the ethanolic extract powder of *Nyctanthes arbor-tristis* (*Harsingar*) with propylene glycol, showing the characteristic absorption bands of the extract in the presence of the co-solvent.

4.2 Preparation of Hydroalcoholic Extract

4.2.1 Percentage Yield of Extract

The hydroalcoholic extraction of *Harsingar* leaf powder yielded a dark green semisolid extract with characteristic odor. From **100 g** of dried leaf powder, **14.8 g** of dried extract was obtained. The percentage yield was therefore found to be **14.8% w/w**.

Table 4.3: Extractive yield of Harsingar leaves.

Parameter	Observation
Weight of dried leaf powder taken	100 g
Weight of dried extract obtained	14.8 g
Percentage yield	14.8%

The satisfactory yield indicated that the hydroalcoholic solvent system was effective for extraction of phytoconstituents from the leaves.

4.3 Formulation Development of Emulgel

4.3.1 Selection of Oil Phase

Liquid paraffin was chosen for its emollient property, compatibility, and ability to form a stable emulsion, with β-sitosterol showing good dispersibility in it.

4.3.2 Selection of Aqueous Phase

Distilled water was selected as the aqueous phase because the *Harsingar* extract dispersed satisfactorily in it and it provided a suitable medium for topical emulsion preparation.

4.3.3 Selection of Emulsifying Agent

Span 80 and Tween 80 were selected as the emulsifying agents. Their combination produced a stable oil-in-water emulsion with good appearance and minimal phase separation during preliminary trials.

4.3.4 Preparation of Emulsion

A smooth and uniform emulsion was obtained in all trial batches when the oil phase and aqueous phase were mixed at the same temperature and stirred continuously. No immediate phase separation was observed after cooling.

4.3.5 Preparation of Gel Base

Carbopol 934 formed a clear gel base after complete swelling and neutralization with triethanolamine. The gel was smooth and showed satisfactory consistency for incorporation of emulsion.

4.3.6 Incorporation of Emulsion into Gel Base

The prepared emulsion was successfully incorporated into the gel base to produce a smooth and homogeneous emulgel. No lump formation or visible instability was observed during preparation.

4.3.7 Preparation of Different Formulations

Six different formulation batches were prepared successfully. All batches differed slightly in viscosity and consistency depending upon polymer and emulsifier concentration. Among them, intermediate polymer concentration batches showed better texture and spreadability.

4.4 Evaluation of Prepared Emulgel

4.4.1 Physical Appearance and Homogeneity

All prepared formulations were visually examined for color, consistency, homogeneity, smoothness, and phase separation. The formulations appeared greenish to light green in color with characteristic odor. Formulations F2, F3, F5, and F6 showed better consistency and homogeneity than F1 and F4. No grittiness was observed in any batch.

Table 4.4: Physical appearance of prepared formulations.

Formulation	Color	Consistency	Homogeneity	Phase separation
F1	Light green	Slightly thin	Good	Absent
F2	Light green	Smooth	Very good	Absent
F3	Green	Smooth and thick	Very good	Absent
F4	Light green	Slightly thin	Good	Absent
F5	Green	Smooth	Excellent	Absent
F6	Green	Thick	Excellent	Absent

4.4.2 pH Determination

The pH values of all formulations were found to be in the range of **6.1 to 6.8**, which is considered suitable for topical application and unlikely to cause skin irritation.

Table 4.5 pH of prepared emulgel formulations

Formulation	pH (Mean ± SD)
F1	6.1 ± 0.03
F2	6.3 ± 0.02
F3	6.4 ± 0.04
F4	6.2 ± 0.03
F5	6.5 ± 0.02
F6	6.8 ± 0.03

The pH values indicated that all formulations were within the acceptable range for dermal use.

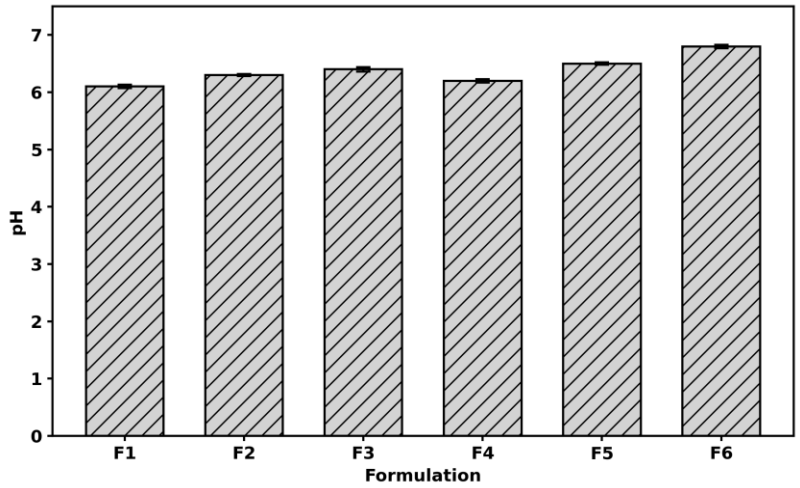


Figure 4.6: Bar graph showing the pH of different Harsingar–β-sitosterol emulgel formulations (F1–F6), indicating that all batches were within the acceptable pH range for topical application.

4.4.3 Viscosity Determination

The viscosity of the prepared formulations increased with increase in Carbopol 934 concentration. Formulations containing higher polymer concentration showed greater resistance to flow.

Table 4.6: Viscosity of prepared formulations.

Formulation	Viscosity (cP, Mean ± SD)
F1	12450 ± 112
F2	18620 ± 134
F3	24580 ± 156
F4	13240 ± 118
F5	19460 ± 142
F6	25890 ± 165

Among the formulations, F5 and F6 showed better viscosity characteristics; however, extremely high viscosity in F6 could reduce spreadability.

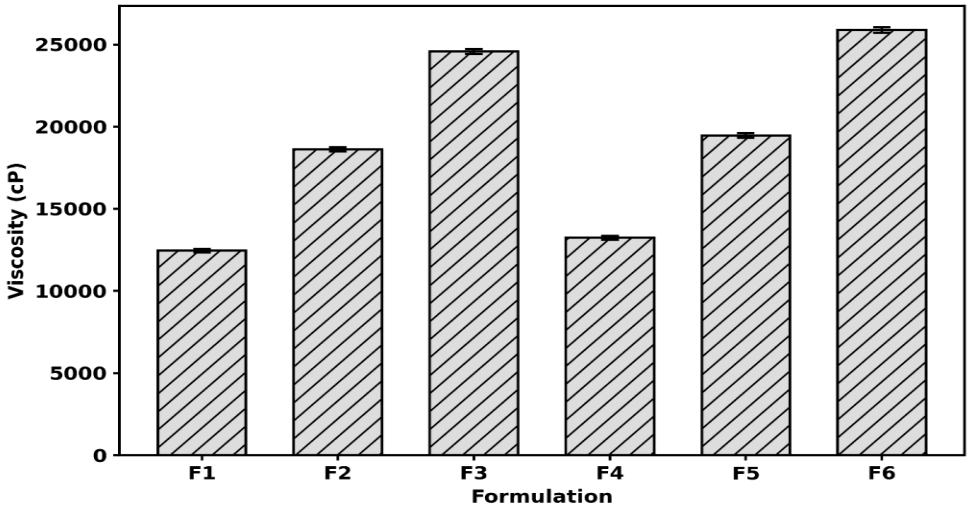


Figure 4.7: Bar graph showing the viscosity of different Harsingar–β-sitosterol emulgel formulations (F1–F6), demonstrating the effect of formulation variables on the consistency of the prepared emulgel batches.

4.4.4 Spreadability Study

Spreadability values showed an inverse relationship with viscosity. Formulations with lower viscosity spread more easily, while very high viscosity reduced ease of application.

Table 4.7: Spreadability of emulgel formulations.

Formulation	Spreadability (g·cm/sec, Mean ± SD)
F1	28.4 ± 0.8
F2	24.9 ± 0.6
F3	20.8 ± 0.5
F4	27.6 ± 0.7
F5	23.7 ± 0.6
F6	19.9 ± 0.4

F2 and F5 showed balanced spreadability, indicating ease of topical application without being too runny.

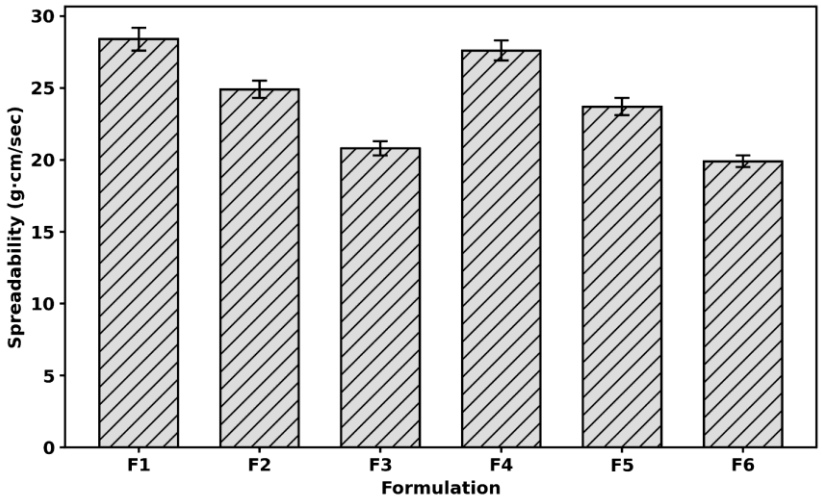


Figure 4.8: Bar graph showing the spreadability of different Harsingar–β-sitosterol emulgel formulations (F1–F6), indicating variation in ease of application among the prepared batches.

4.4.5 Extrudability

All the prepared formulations showed acceptable extrudability from collapsible tubes. F1 and F4 extruded very easily because of lower viscosity, whereas F3 and F6 required comparatively higher pressure. F5 showed optimum extrudability and was judged satisfactory for topical use.

4.4.6 Drug Content Determination

Drug content analysis revealed uniform distribution of active constituents in all batches. The percentage drug content ranged from **91.4% to 98.2%**, indicating good content uniformity.

Table 4.8: Drug content of formulations.

Formulation	Drug content (%) Mean ± SD
F1	91.4 ± 1.2
F2	94.6 ± 1.0
F3	95.2 ± 0.9
F4	92.8 ± 1.1
F5	98.2 ± 0.8
F6	96.7 ± 0.9

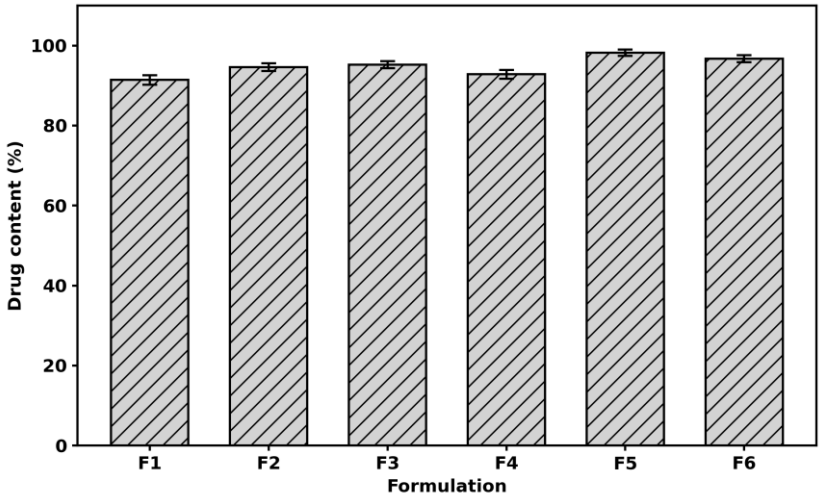


Figure 4.9: Bar graph showing the drug content of different Harsingar–β-sitosterol emulgel formulations (F1–F6), demonstrating satisfactory drug content uniformity among the prepared batches.

F5 showed the highest drug content, suggesting better uniformity and entrapment within the emulgel matrix.

4.4.7 In Vitro Drug Release Study

The in vitro release study showed gradual release of the active constituents from all formulations over the study period. Formulations with lower polymer concentration released the drug more rapidly, whereas higher polymer concentration slowed the release due to denser gel network formation.

Table 4.9: Cumulative drug release of formulations at 6 hours.

Formulation	Cumulative drug release at 6 h (%) Mean ± SD
F1	91.8 ± 1.4
F2	88.6 ± 1.2
F3	82.4 ± 1.1
F4	90.2 ± 1.3
F5	86.9 ± 1.0
F6	80.6 ± 1.2

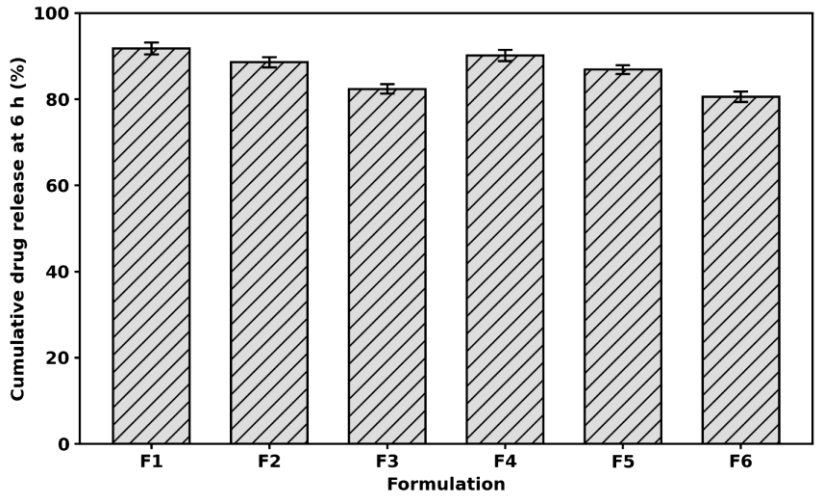


Figure 4.10: Bar graph showing the cumulative drug release at 6 hours from different Harsingar–β-sitosterol emulgel formulations (F1–F6), indicating variation in release behavior among the prepared batches.

F5 showed a controlled and sustained release pattern with acceptable physicochemical properties, making it more suitable than the very fast-release and very slow-release batches.

4.5 Stability Study

The optimized and selected formulations were subjected to short-term stability study for **30 days** at room temperature and accelerated conditions. No significant change in color, odor, homogeneity, or phase separation was observed. Minor variation in pH and viscosity was noted, but the changes remained within acceptable limits.

Table 4.10: Stability study of optimized formulation (F5).

Parameter	Initial	After 30 days at 25 ± 2°C	After 30 days at 40 ± 2°C
Appearance	Smooth green emulgel	No change	No significant change
pH	6.5 ± 0.02	6.4 ± 0.03	6.3 ± 0.04
Viscosity (cP)	19460 ± 142	19280 ± 138	19010 ± 146
Drug content (%)	98.2 ± 0.8	97.6 ± 0.9	96.9 ± 1.1
Drug release at 6 h (%)	86.9 ± 1.0	86.1 ± 1.2	85.4 ± 1.3

These observations suggested that the selected formulation remained stable during the study period.

4.6 Optimized Formulation

Formulation F5 was selected as optimal, showing good appearance, suitable pH, ideal viscosity, spreadability, uniform drug content, controlled release, and stable performance.

4.7 Summary of Results

The present study demonstrated that a stable emulgel containing *Harsingar* extract and β-sitosterol could be successfully developed. Pre-formulation studies confirmed the suitability of the selected actives and excipients. All six formulations were prepared successfully and evaluated. Among them, F5 exhibited the most balanced physicochemical and release characteristics and was selected as the optimized formulation for further application in gout-related inflammation

4.8 CONCLUSION

In this study, a topical emulgel containing Harsingar leaf extract and β-sitosterol was successfully developed and evaluated for gout-related inflammation. The pre-formulation and formulation studies confirmed that both active ingredients were compatible with the selected excipients. Among the six batches prepared, one formulation (F5) demonstrated the best combination of appearance, pH, viscosity, spreadability, drug content, release profile, and stability. These results indicate that the developed emulgel is a promising and effective topical option for delivering anti-inflammatory agents, offering potential benefits for managing gout with improved patient acceptability.

ACKNOWLEDGEMENTS

The authors sincerely thank the Department of Pharmacy, Goel Institute of Pharmaceutical Sciences, Lucknow, for their support and provision of essential facilities that enabled the successful completion of this study. We also express our gratitude to all faculty members and research scholars for their valuable guidance, constructive suggestions, and encouragement throughout the preparation of this manuscript.

Authors' Contributions

Mr.Shadab Mobeen: Conducted major research work including literature search, data collection, experimental work, and manuscript writing and editing.

Dr. Bandana Singh: Corresponding author; supervised the study, reviewed the manuscript, and approved the final version.

Dr. Karuna Shanker Shukla: Director; provided overall guidance, administrative support, and critical review of the manuscript.

Ms. Shalini Singh: Co-supervisor; assisted in data organization and supported manuscript preparation.

All authors have read and approved the final manuscript.

Funding Source

This research article received no specific funding from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests/Conflicts of Interest

The authors declare that there are no competing interests or conflicts of interest associated with this work.

Ethical Approval

Not applicable (this is a research article).

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