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Formulation Development and Evaluation of Herbal Topical Liposomal Gel for Management of Acne

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ABSTRACT

Acne vulgaris is a common chronic inflammatory skin disorder affecting a large proportion of the population, particularly adolescents, and is associated with microbial infection, excessive sebum production, and inflammatory responses. Conventional therapies often present limitations such as skin irritation, antibiotic resistance, and poor patient compliance, necessitating the development of safer and more effective alternatives. The present study aimed to develop and evaluate a herbal topical liposomal gel formulation for effective acne management using plant-derived bioactive compounds. Medicinal plants Berberis aristata, Curcuma longa, and Moringa oleifera were selected based on their known antimicrobial, anti-inflammatory, and antioxidant properties. The plant materials were authenticated, extracted using hydroalcoholic methods, and subjected to phytochemical screening and standardization, confirming the presence of key secondary metabolites such as alkaloids, flavonoids, phenolics, and tannins. Liposomal formulations were prepared using the thin-film hydration technique and incorporated into a Carbopol-based gel. The formulations were evaluated for particle size, zeta potential, entrapment efficiency, pH, viscosity, spreadability, and drug content. The liposomes exhibited nanoscale size (180–250 nm), good stability, and high entrapment efficiency (72–85%). The formulated gel showed suitable physicochemical properties for topical application and uniform drug distribution. In-vitro drug release studies demonstrated sustained and controlled release of phytoconstituents over an extended period, following diffusion-controlled kinetics (Higuchi and Korsmeyer–Peppas models). Stability studies indicated no significant changes in formulation characteristics, confirming its stability. In conclusion, the developed herbal liposomal gel represents a promising, safe, and effective topical drug delivery system for acne management, offering improved therapeutic efficacy, enhanced skin penetration, controlled drug release, and reduced side effects compared to conventional treatments.

Keywords
Acne vulgaris,
Herbal liposomal gel,
Berberis aristata,
Curcuma longa,
Moringa oleifera,
Phytoconstituents,
Anti-inflammatory,

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Introduction

Berberis aristata

Biological Source and Family

Berberis aristata DC. commonly known as Daruharidra, belongs to the family *Berberidaceae*. It consists of the dried stem bark and roots of the plant.

Geographical Source

The plant is widely distributed in the Himalayan region of India, particularly in Himachal Pradesh, Uttarakhand, and Nepal, at altitudes ranging from 2000 to 3000 meters.

Morphological Characteristics

Berberis aristata is a spiny deciduous shrub reaching a height of about 2–3 meters. The stem is woody with yellowish inner bark. Leaves are arranged in tufts, simple, obovate, and serrated. Flowers are yellow and appear in racemes, while fruits are oblong berries that turn red upon ripening.

Phytochemical Constituents

The plant is rich in isoquinoline alkaloids, predominantly berberine, along with berbamine, palmatine, and oxyacanthine. These compounds are responsible for its antimicrobial and anti-inflammatory properties.

Pharmacological Activities

Berberis aristata exhibits antimicrobial, anti-inflammatory, antioxidant, and wound healing activities. It is particularly effective against acne-causing bacteria due to the presence of berberine.

Uses in Present Study

In the present study, Berberis aristata extract serves as a primary antimicrobial agent targeting acne-causing microorganisms.

Fig.1: *Berberis aristata*

Curcuma longa

Biological Source and Family

Curcuma longa Linn. commonly known as turmeric, belongs to the family Zingiberaceae. It consists of the dried rhizomes of the plant.

Geographical Source

The plant is cultivated extensively throughout India, particularly in Andhra Pradesh, Tamil Nadu, Maharashtra, and West Bengal.

Morphological Characteristics

Curcuma longa is a perennial herb with underground rhizomes that are yellow to orange in color. Leaves are large, oblong, and arranged in two rows. The plant bears yellow flowers arranged in spikes.

Phytochemical Constituents

The major constituents include curcuminoids (curcumin, demethoxycurcumin, bisdemethoxycurcumin), volatile oils (turmerone, atlantone), and other phenolic compounds.

Pharmacological Activities

Turmeric exhibits potent anti-inflammatory, antioxidant, antimicrobial, and wound healing properties. Curcumin plays a crucial role in reducing inflammation and oxidative stress associated with acne.

Uses in Present Study

In this study, Curcuma longa extract is incorporated for its anti-inflammatory and antioxidant properties to reduce acne lesions and skin irritation.

Fig.2: *Curcuma longa*

Moringa oleifera

Biological Source and Family

Moringa oleifera Lam., commonly known as drumstick tree, belongs to the family Moringaceae. The leaves are primarily used for medicinal purposes.

Geographical Source

The plant is widely cultivated across India, especially in southern regions such as Andhra Pradesh, Tamil Nadu, and Karnataka.

Morphological Characteristics

Moringa oleifera is a small to medium-sized tree with compound leaves consisting of small oval leaflets. The plant produces long pods (drumsticks) and white fragrant flowers.

Phytochemical Constituents

The leaves contain flavonoids such as quercetin and kaempferol, along with vitamins, phenolic acids, and minerals. These compounds contribute to its antioxidant and anti-inflammatory properties.

Pharmacological Activities

Moringa oleifera exhibits antioxidant, antimicrobial, anti-inflammatory, and skin-protective activities. It is effective in reducing oxidative stress and improving skin health.

Uses in Present Study

In the present study, Moringa oleifera extract is utilized as a natural source of flavonoids, particularly quercetin, to enhance antioxidant activity and support acne treatment.

Fig.3: *Moringa oleifera*

2. Materials and Methods

Collection and Authentication of Plant Material

Fresh plant materials selected for the present investigation included Berberis aristata (stem bark), Curcuma longa (rhizomes), and Moringa oleifera (leaves), which are known sources of berberine, curcuminoids, and quercetin respectively. The plant materials were collected from local regions during their appropriate harvesting season to ensure maximum phytochemical content. The collected materials were washed thoroughly with distilled water to remove extraneous matter and shade dried at room temperature (25–30°C) for a period of 10–15 days to prevent degradation of thermolabile constituents. The dried plant materials were pulverized using a mechanical grinder to obtain coarse powder and stored in airtight containers until further use. Authentication of plant materials was carried out by a qualified taxonomist, and voucher specimens were preserved in the institutional herbarium for future reference.

Preparation of Plant Extracts

The dried and powdered plant materials were subjected to extraction using a hydroalcoholic solvent system. Approximately 100 g of each powdered drug was extracted separately by Soxhlet apparatus using 70% ethanol as solvent for 6–8 hours. The extraction process was continued until the solvent in the siphon tube became colorless. The obtained extracts were filtered through muslin cloth followed by Whatman filter paper and concentrated under reduced pressure using a rotary evaporator. The concentrated extracts were further dried in a desiccator to obtain a semisolid mass and stored in airtight containers at refrigerated conditions until further use.

Preliminary Phytochemical Screening

The prepared extracts were subjected to qualitative phytochemical screening using standard pharmacognostic procedures to detect the presence of various secondary metabolites such as alkaloids, flavonoids, phenolic compounds, tannins, saponins, and terpenoids. Specific chemical tests such as Dragendorff's test for alkaloids, Shinoda test for flavonoids, ferric chloride test for phenolics and tannins, frothing test for saponins, and Salkowski test for terpenoids were performed to confirm the presence of respective phytoconstituents.

Standardization of Extracts

Standardization of the extracts was carried out by spectrophotometric and spectroscopic techniques. The λmax of

each extract was determined using a UV-visible spectrophotometer by scanning in the range of 200–800 nm. Calibration curves were prepared using appropriate dilutions of extracts. Fourier Transform Infrared (FTIR) spectroscopy was performed to identify characteristic functional groups present in the extracts and to confirm the chemical integrity of phytoconstituents.

Preparation of Herbal Liposomes

The liposomal formulation containing herbal extracts was prepared by thin film hydration technique. Accurately weighed quantities of soya lecithin and cholesterol were dissolved in a mixture of chloroform and methanol in the ratio of 2:1 (v/v) in a round-bottom flask. The combined plant extracts were incorporated into the lipid phase and mixed thoroughly. The organic solvents were removed under reduced pressure using a rotary evaporator to form a thin lipid film on the walls of the flask. The film was hydrated using phosphate buffer pH 7.4 with gentle rotation to obtain multilamellar vesicles. The liposomal suspension was then subjected to probe sonication to reduce particle size and obtain a uniform dispersion. The prepared liposomes were stored at 4°C for further use.

Formulation of Herbal Liposomal Gel

A suitable gel base was prepared using Carbopol 934 as a gelling agent. The required quantity of Carbopol was dispersed in distilled water with continuous stirring and allowed to hydrate and swell overnight. The pH of the dispersion was adjusted using triethanolamine to obtain a transparent gel base. The prepared liposomal suspension containing herbal extracts was gradually incorporated into the gel base with continuous stirring to ensure uniform distribution. Propylene glycol was added as a penetration enhancer. The final volume of the formulation was adjusted with distilled water and the gel was stored in suitable containers.

Composition of Herbal Liposomal Gel Formulations

Different batches of liposomal gel were prepared by varying the concentration of herbal extracts and lipid components.

Table 1: Composition of Herbal Liposomal Gel

Ingredients	F1 (% w/w)	F2 (% w/w)	F3 (% w/w)
Berberis aristata extract	1.0	1.5	2.0
Curcuma longa extract	1.0	1.5	2.0
Moringa oleifera extract	1.0	1.5	2.0
Soya lecithin	2.0	3.0	4.0
Cholesterol	0.5	1.0	1.5
Carbopol 934	1.0	1.0	1.0
Propylene glycol	10	10	10
Triethanolamine	q.s.	q.s.	q.s.
Distilled water	q.s. to 100	q.s. to 100	q.s. to 100

Evaluation of Liposomal Gel

The prepared formulations were evaluated for various physicochemical parameters. The appearance and homogeneity of the gel were assessed visually. The pH of the formulations was determined using a calibrated digital pH meter. Viscosity measurements were carried out using a Brookfield viscometer at controlled temperature. Spreadability was determined using the slide method. Drug content was estimated by dissolving a known quantity of gel in phosphate buffer pH 7.4 followed by spectrophotometric analysis.

In-vitro Drug Release Study

The in vitro drug release study was carried out using a Franz diffusion cell apparatus. The cellophane membrane was soaked in phosphate buffer pH 7.4 prior to the experiment. The gel formulation was placed in the donor compartment, while the receptor compartment was filled with phosphate buffer maintained at 35 ± 0.5°C and continuously stirred. Samples were withdrawn at predetermined intervals and replaced with fresh buffer. The amount of drug released was determined spectrophotometrically.

Stability Studies

The optimized formulation was subjected to accelerated stability studies under controlled conditions of 40°C ± 2°C and 75% ± 5% relative humidity for a period of three months. Samples were withdrawn at regular intervals and evaluated for physical appearance, pH, viscosity, and drug content.

Statistical Analysis

All experimental data were expressed as mean ± standard deviation. Statistical analysis was performed using appropriate software, and significance of differences was determined using analysis of variance (ANOVA).

Summary of Methodology

The study was systematically carried out starting from collection and authentication of plant materials, followed by extraction, phytochemical screening, and standardization. The extracts were incorporated into liposomal systems, which were further formulated into topical gel and evaluated for various parameters.

Results and Discussion

Organoleptic and Macroscopic Evaluation of Plant Materials: The collected plant materials, namely Berberis aristata stem bark, Curcuma longa rhizomes, and Moringa oleifera leaves, were subjected to organoleptic evaluation. The stem bark of Berberis aristata was found to be yellowish-brown in color with a characteristic bitter taste, while Curcuma longa rhizomes exhibited a bright yellow color with a pungent odor. The leaves of Moringa oleifera were green in color with a slightly bitter taste. These observations were consistent with standard pharmacognostic descriptions, confirming the authenticity of the crude drugs.

Extraction and Percentage Yield

The hydroalcoholic extraction of powdered plant materials yielded semisolid extracts with varying percentage yields. The variation in yield can be attributed to differences in phytochemical composition and solubility of constituents in the solvent system used.

Table 1: Percentage Yield of Extracts

Plant Source	Extract Obtained (g)	Percentage Yield (%)
Berberis aristata	18.5	18.5
Curcuma longa	22.3	22.3
Moringa oleifera	16.8	16.8

The highest yield was obtained from Curcuma longa, which may be due to the presence of abundant curcuminoids and resinous constituents soluble in hydroalcoholic solvent.

Preliminary Phytochemical Screening

Qualitative phytochemical screening confirmed the presence of major secondary metabolites responsible for therapeutic activity.

Table 2: Phytochemical Screening Results

Phytoconstituent	Berberis	Curcuma	Moringa
Alkaloids	Present	Absent	Absent
Flavonoids	Present	Present	Present
Phenolics	Present	Present	Present
Tannins	Present	Absent	Present
Saponins	Absent	Present	Present

The presence of alkaloids in Berberis aristata confirms berberine content, while flavonoids and phenolics in all extracts support antioxidant and anti-inflammatory potential, essential for acne management.

Spectral Analysis and Standardization

UV-visible spectrophotometric analysis of extracts showed characteristic absorption maxima corresponding to major phytoconstituents. FTIR spectra revealed distinct functional groups such as hydroxyl, carbonyl, and aromatic rings, confirming the chemical integrity of plant extracts and absence of degradation.

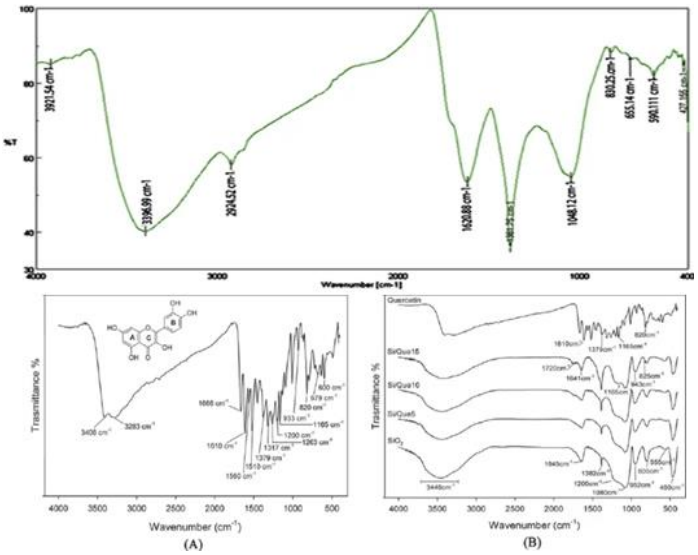

Fig.4: FT-IR Spectra of Herbal Extracts

The observed peaks were in agreement with reported literature values, confirming successful extraction of active phytoconstituents.

Characterization of Liposomes

The herbal extracts were successfully incorporated into liposomes using thin film hydration technique. The prepared liposomes were evaluated for particle size, zeta potential, and entrapment efficiency.

Table 3: Characterization of Liposomes

Parameter	Result
Particle size	180–250 nm
Zeta potential	-25 to -32 mV
Entrapment efficiency	72–85%

The nanoscale size of liposomes indicates efficient vesicle formation suitable for enhanced skin penetration. The negative zeta potential values suggest good stability due to electrostatic repulsion between vesicles. High entrapment efficiency indicates successful incorporation of herbal extracts within the lipid bilayer.

Evaluation of Herbal Liposomal Gel

The prepared liposomal gel formulations were evaluated for physicochemical properties.

Table 4: Evaluation of Liposomal Gel

Parameter	F1	F2	F3
pH	6.5	6.7	6.8
Viscosity (cps)	2800	3200	3600
Spreadability (g·cm/sec)	18.5	16.2	14.8
Drug content (%)	96.8	98.5	99.2

The pH of all formulations was found to be within the acceptable range for topical application, indicating suitability for skin use without irritation. Viscosity increased with higher lipid concentration, which influenced spreadability inversely. Drug content values close to 100% confirmed uniform distribution of phytoconstituents within the gel matrix.

In-vitro Drug Release Study

The in vitro drug release study demonstrated sustained release of phytoconstituents from the liposomal gel over an extended period.

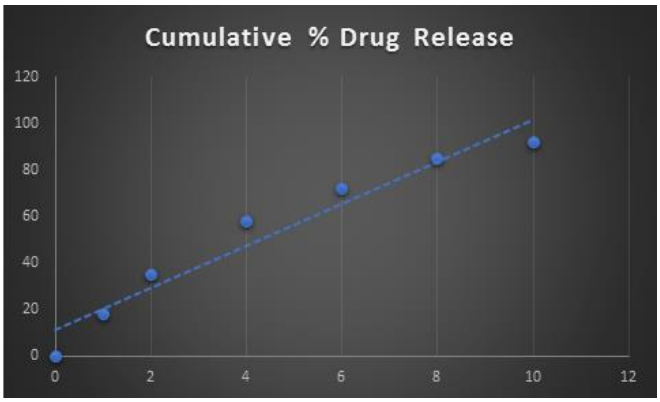

Fig. 5: Cumulative % Drug Release vs Time

(Shows gradual release reaching ~90% over 8–10 hours): The sustained release behavior can be attributed to encapsulation of extracts within liposomal vesicles, which act as reservoirs and control drug diffusion.

Drug Release Kinetics

The release data were fitted into different kinetic models, and the best fit was observed with Higuchi and Korsmeyer-Peppas models, indicating diffusion-controlled release mechanism.

Stability Studies

The optimized formulation (F2) was subjected to accelerated stability studies.

Table 5: Stability Study Results

Parameter	Initial	After 3 Months
pH	6.7	6.6
Viscosity	3200 cps	3150 cps
Drug content	98.5%	97.8%

No significant changes were observed in physicochemical parameters, indicating good stability of the formulation under accelerated conditions.

Overall Discussion

The present study successfully demonstrated the integration of pharmacognosy and novel drug delivery systems. Starting from crude plant materials, the extracts were effectively prepared, standardized, and incorporated into liposomal vesicles. The liposomal gel formulation exhibited desirable physicochemical properties, sustained drug release, and stability. The presence of bioactive phytoconstituents such as berberine, curcuminoids, and quercetin contributes to antimicrobial, anti-inflammatory, and antioxidant effects, making the formulation suitable for acne management. The liposomal system significantly enhanced the delivery of herbal actives through the skin, overcoming limitations of conventional topical formulations. Thus, the developed herbal liposomal gel represents a promising, safe, and effective approach for acne treatment.

Discussion

The present investigation was undertaken with the objective of developing a herbal topical liposomal gel for the effective management of acne vulgaris using pharmacognostically validated plant materials. The study was initiated with the selection, collection, and authentication of Berberis aristata, Curcuma longa, and Moringa oleifera, which are well-known for their antimicrobial, anti-inflammatory, and antioxidant properties. The collected plant materials were processed, dried, and subjected to hydroalcoholic extraction to obtain phytoconstituent-rich extracts. Preliminary phytochemical screening of the extracts confirmed the presence of important secondary metabolites such as alkaloids, flavonoids, phenolics, and tannins, which are responsible for therapeutic activity against acne. Standardization of the extracts using spectrophotometric and FTIR techniques ensured the presence and integrity of active phytoconstituents. The prepared extracts were successfully incorporated into liposomal vesicles using the thin film hydration method. The liposomes exhibited nanoscale particle size, satisfactory entrapment efficiency, and good stability, indicating their suitability as carriers for topical drug delivery. The incorporation of liposomes into a Carbopol-based gel resulted in a smooth, homogeneous, and stable formulation.

The formulated herbal liposomal gel was evaluated for various physicochemical parameters, including pH, viscosity, spreadability, and drug content. The results indicated that the gel was suitable for topical application, with pH within the acceptable range for skin and adequate spreadability and consistency. The in vitro drug release studies demonstrated a sustained release pattern over an extended period, which is advantageous for prolonged therapeutic action. The release kinetics suggested a diffusion-controlled mechanism, supporting the role of liposomal encapsulation in controlled drug delivery.
Stability studies conducted under accelerated conditions revealed that the formulation remained stable with no significant changes in its physicochemical properties, confirming its suitability for long-term storage.

Conclusion

The present study successfully established a pharmacognosy-based approach for the development of a herbal liposomal gel formulation intended for acne management. The integration of plant-derived extracts with a novel liposomal delivery system enhanced the therapeutic potential of the formulation by improving drug stability, skin penetration, and controlled release characteristics. The results clearly demonstrate that the developed formulation possesses desirable physicochemical properties, sustained drug release behavior, and good stability, making it a promising alternative to conventional synthetic therapies. The use of herbal constituents minimizes the risk of adverse effects such as skin irritation and antibiotic resistance, thereby improving patient compliance. Thus, the formulated herbal liposomal gel can be considered a safe, effective, and innovative topical delivery system for the management of acne vulgaris. Further studies involving in vivo evaluation and clinical investigations may be carried out to establish its therapeutic efficacy and commercial applicability.

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Conflict of Interests

The authors declare no conflict of interest

Ethics Approval

Not applicable

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AI Tool Declaration

The authors declare that no AI and related tools are used to write the scientific content of this manuscript.

Data Availability

Data will be available on request

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