

Formulation and Evaluation of Nanoemulsion Based Herbal Anti Acne Gel

¹Najan Sumit Suresh, ²Shirsath Rameshwar Vishnu, ³Nikita Sanjay Salekar,

⁴Ubale Nikita Sudhakar, ⁵Gaikwad Kirti Sudhakar

^{1,2,3,4,5}Shri Laxmanrao Trymbakrao Nakade Pharmacy College Dhorjalgaon Ne

Abstract—Acne vulgaris is one of the most common dermatological disorders affecting adolescents and young adults worldwide. It is primarily caused by excessive sebum production, follicular hyperkeratinization, bacterial infection, and inflammation. Conventional anti-acne formulations such as antibiotics and retinoids are effective but often produce side effects including dryness, irritation, erythema, and microbial resistance. Therefore, herbal formulations incorporated into advanced drug delivery systems are gaining importance due to improved efficacy and safety.

Nanoemulsion-based topical systems enhance drug penetration, stability, and bioavailability of herbal active constituents. The present study aimed to formulate and evaluate a nanoemulsion-based herbal anti-acne gel containing plant extracts with antimicrobial and anti-inflammatory properties. The nanoemulsion was prepared using high energy emulsification method and incorporated into a gel base. The formulation was evaluated for particle size, pH, viscosity, spreadability, drug content, stability, and antimicrobial activity against acne-causing bacteria. The results indicated that the developed nanoemulsion gel showed suitable physicochemical properties, good stability, and significant antimicrobial activity. The study concludes that nanoemulsion-based herbal gel can be considered a promising and safe alternative for the management of acne vulgaris.

Index Terms—Nanoemulsion, Anti-acne gel, Herbal formulation, Topical drug delivery, Acne vulgaris, Nanotechnology

I. INTRODUCTION

Acne vulgaris is a chronic inflammatory disorder of the pilosebaceous unit characterized by comedones, papules, pustules, nodules, and cysts. It mainly affects adolescents due to hormonal changes but may also occur in adults [1]. The pathogenesis of acne involves

increased sebum production, abnormal keratinization, colonization of *Cutibacterium acnes*, and inflammatory responses [2].

Conventional topical treatments such as benzoyl peroxide, retinoids, and antibiotics are widely used in acne therapy. However, prolonged use of these agents may lead to skin irritation, dryness, erythema, and antibiotic resistance [3]. Hence, there is a need for safer alternatives with enhanced efficacy.

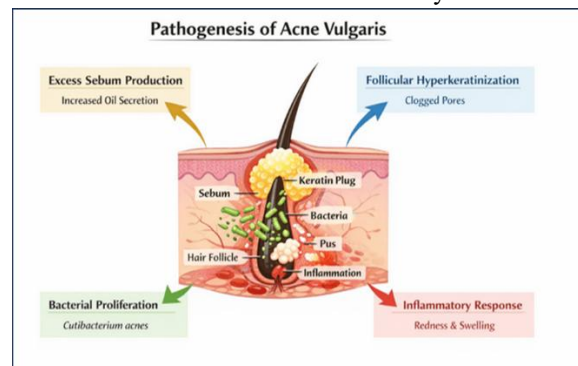


Figure 1: Pathogenesis of acne vulgaris

Herbal medicines have been widely used for the treatment of skin disorders due to their antimicrobial, anti-inflammatory, antioxidant, and healing properties [4]. Plant-derived compounds such as flavonoids, phenolics, and terpenoids exhibit significant anti-acne activity.

Nanoemulsion is a thermodynamically stable isotropic system consisting of oil, water, surfactant, and co-surfactant with droplet size typically ranging from 20–200 nm [5]. Nanoemulsions enhance drug solubility, skin penetration, and therapeutic effectiveness of active constituents [6]. Incorporation of nanoemulsion into gel base improves patient compliance and topical retention.

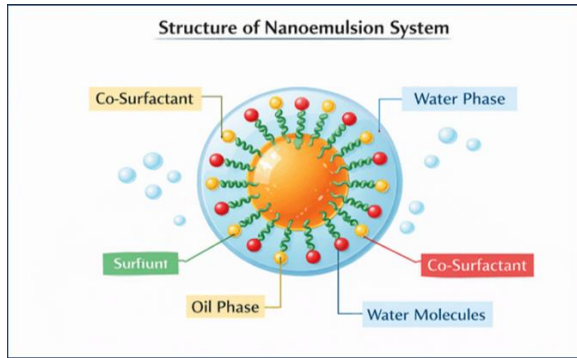


Figure 2: Structure of nanoemulsion system

Therefore, the present study was undertaken to formulate and evaluate a nanoemulsion-based herbal anti-acne gel for effective management of acne vulgaris.

Aim of the Study

To formulate and evaluate a nanoemulsion-based herbal anti-acne gel for topical treatment of acne vulgaris.

Objectives of the Study

1. To select suitable herbal extract for anti-acne activity.
2. To formulate nanoemulsion using appropriate oil, surfactant, and co-surfactant.
3. To incorporate nanoemulsion into gel base.
4. To evaluate physicochemical parameters.
5. To study antimicrobial activity against acne-causing bacteria.
6. To perform stability studies.

II. REVIEW OF LITERATURE

Acne vulgaris is a multifactorial inflammatory skin disorder involving microbial infection, excessive sebum production, and inflammatory mediators. Recent research has focused on herbal formulations and advanced delivery systems to improve therapeutic outcomes and reduce adverse effects of conventional drugs.

Nanoemulsion systems have gained considerable attention as topical drug delivery carriers due to their small droplet size, high surface area, and enhanced penetration through the stratum corneum. Shakeel et al. reported that nanoemulsion formulations significantly enhance the permeability and

bioavailability of lipophilic drugs applied topically [7]. The small droplet size allows better contact with the skin surface, improving drug absorption.

Lawrence and Rees described nanoemulsions as kinetically stable systems capable of improving solubilization and stability of active ingredients [8]. They concluded that nanoemulsions are ideal for topical therapy due to improved dispersion and patient acceptability.

Herbal extracts have been widely used in acne treatment due to antimicrobial and anti-inflammatory properties. Tea tree oil and neem extracts were reported to exhibit strong antibacterial activity against *Cutibacterium acnes* [9]. Similarly, aloe vera extract reduces inflammation and promotes healing of acne lesions [10].

A study by Gupta et al. formulated herbal anti-acne gel containing plant extracts and observed significant reduction in bacterial growth and inflammation [11]. Another study by Sharma et al. developed nanoemulsion gel and reported improved skin penetration and faster therapeutic response compared to conventional gel [12].

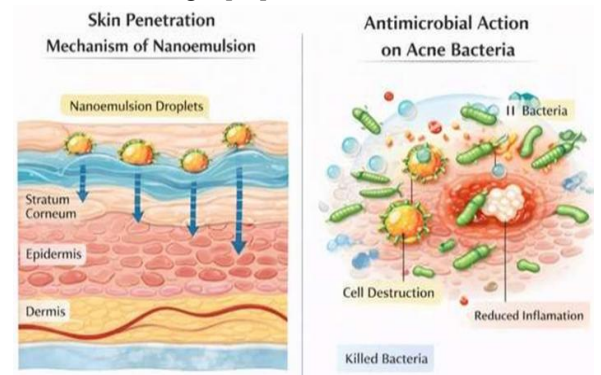


Figure 3: Skin penetration mechanism of nanoemulsion and antimicrobial action on acne bacteria

Kotta et al. demonstrated that nanoemulsion-based topical formulations enhance retention time on skin and improve stability of herbal actives [13]. The authors suggested that combining herbal extracts with nanoemulsion delivery systems can significantly enhance therapeutic efficacy.

These studies indicate that nanoemulsion-based herbal gels offer promising advantages such as improved penetration, stability, and antimicrobial activity. However, limited research has been conducted on nanoemulsion-based herbal anti-acne gels combining

multiple evaluation parameters in a single study. Therefore, the present study was undertaken to formulate and evaluate a nanoemulsion-based herbal anti-acne gel.

Sr. No.	Author	Year	Formulation	Major Findings
1	Shakeel et al.	2009	Nanoemulsion	Improved permeability
2	Lawrence & Rees	2012	Nanoemulsion	Enhanced stability
3	Gupta et al.	2015	Herbal gel	Anti-acne activity
4	Sharma et al.	2018	Nano gel	Better penetration
5	Kotta et al.	2020	Nanoemulsion	Improved retention
6	Lee et al.	2013	Tea tree oil	Antibacterial

Table 1: Summary of Previous Studies on Nanoemulsion and Anti-Acne Formulations

III. MATERIALS AND METHODS

3.1 Materials

Selected herbal extract (Neem/Tea tree/Aloe anti-acne active), Tween-80 (surfactant), Propylene glycol (co-surfactant), Clove oil (oil phase), Carbopol 940 (gelling agent), Triethanolamine, Methyl paraben, Propyl paraben, Distilled water, Mueller Hinton agar, Cutibacterium acnes culture, and standard laboratory glassware were used in the present study [14].

3.2 Selection of Herbal Extract

Herbal extracts possessing antimicrobial and anti-inflammatory activity against acne-causing bacteria were selected. The extract was evaluated based on solubility in oil phase and antibacterial activity [15].

3.3 Solubility Study

The solubility of herbal extract was determined in different oils, surfactants, and co-surfactants. Excess extract was added to each solvent and shaken for 24 hours. The sample was centrifuged and supernatant analyzed spectrophotometrically [16].

3.4 Construction of Pseudo-Ternary Phase Diagram

Pseudo-ternary phase diagram was constructed using water titration method. Oil, surfactant, and co-surfactant were mixed in different ratios and titrated with distilled water to identify nanoemulsion region.

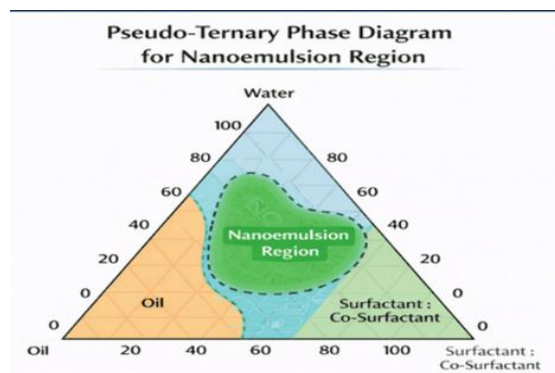


Figure 4: Pseudo-ternary phase diagram for nanoemulsion region

3.5 Preparation of Nanoemulsion

Nanoemulsion was prepared using high-energy emulsification method. The oil phase containing herbal extract was mixed with surfactant and co-surfactant, followed by dropwise addition of aqueous phase under continuous magnetic stirring at 3000 rpm until transparent nanoemulsion was formed [17].

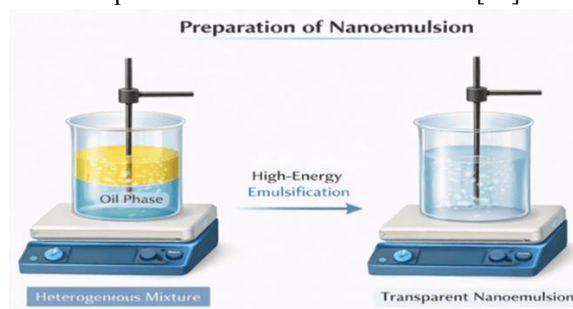


Figure 5: Preparation of nanoemulsion

3.6 Preparation of Nanoemulsion Gel

Carbopol 940 was dispersed in distilled water and allowed to swell for 24 hours. Prepared nanoemulsion was incorporated into gel base with gentle stirring. Triethanolamine was added to adjust pH and obtain clear gel [18].

3.7 Composition of Nanoemulsion Gel

Ingredient	Quantity	Function
Herbal extract	1 %	Anti-acne agent
Clove oil	5 %	Oil phase
Tween-80	25 %	Surfactant
Propylene glycol	15 %	Co-surfactant
Carbopol 940	1 %	Gelling agent
Triethanolamine	q.s.	pH adjustment
Methyl paraben	0.2 %	Preservative
Propyl paraben	0.1 %	Preservative
Distilled water	q.s.	Vehicle

Table 2: Composition of Nano Emulsion-Based Herbal Anti-Acne Gel

3.8 Evaluation of Nano emulsion

3.8.1 Droplet Size and Polydispersity Index

Measured using dynamic light scattering particle size analyzer [19].

3.8.2 Zeta Potential

Determined using zeta potential analyzer to evaluate stability [20].

3.8.3 pH

Measured using digital pH meter.

3.8.4 Viscosity

Measured using Brookfield viscometer.

3.8.5 Spreadability

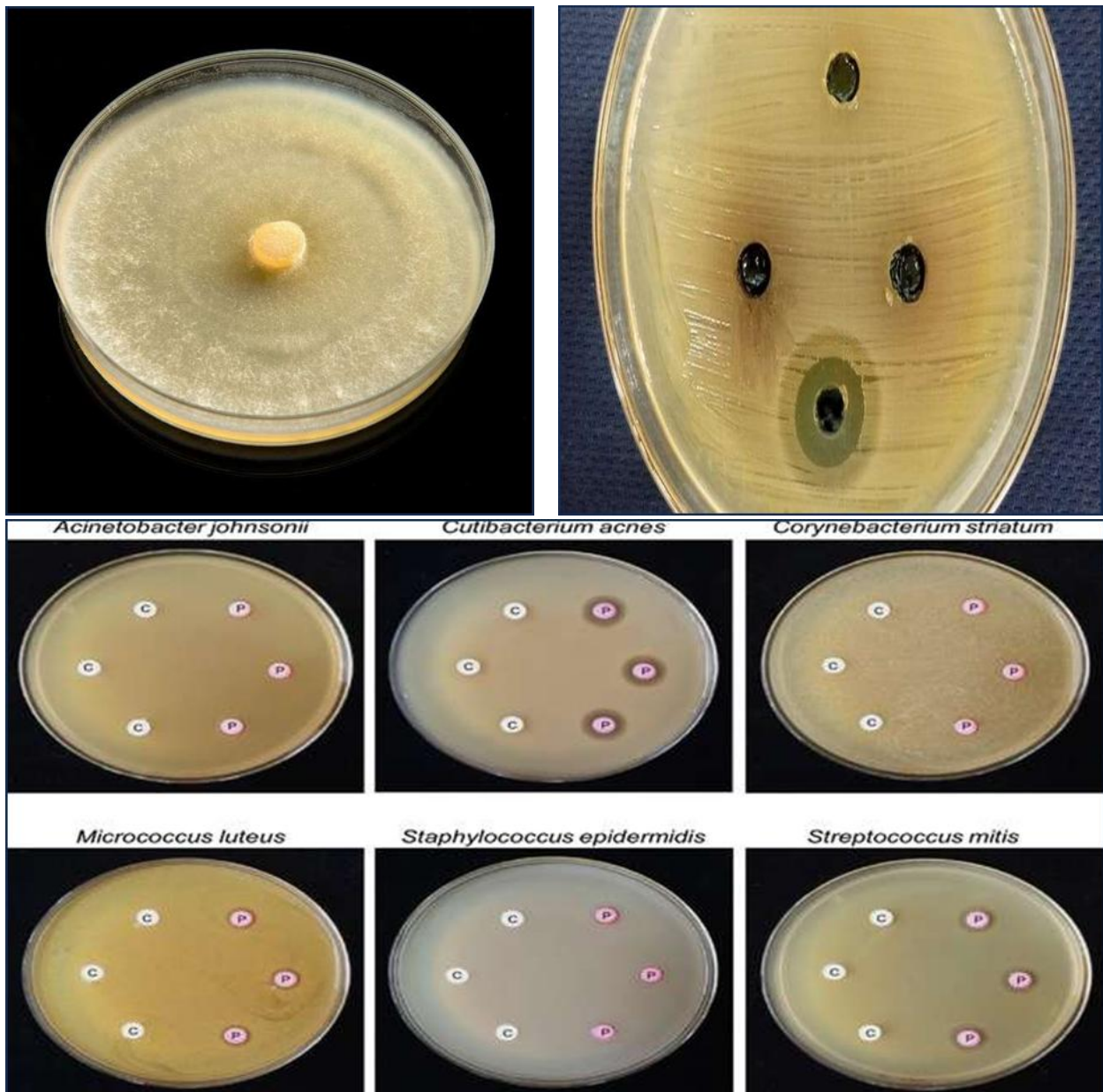
Calculated using glass slide method.

3.9 Drug Content

1 g gel dissolved in methanol and analyzed using UV spectrophotometer at λ_{max} of herbal extract [21].

3.10 In-vitro Antimicrobial Activity

Agar well diffusion method was used against *Cutibacterium acnes*. Zone of inhibition measured after 24 h incubation [22].



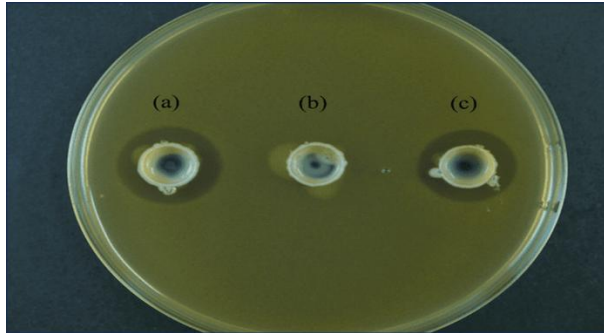


Figure 6: Antimicrobial activity testing

3.11 Stability Studies

Formulation stored at 4°C, 25°C, and 40°C for 30 days and evaluated for phase separation, pH, and viscosity changes [23].

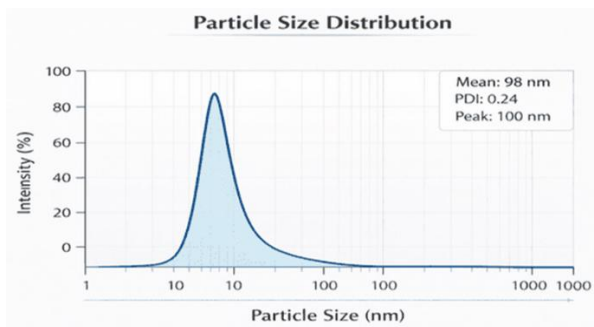
IV. RESULTS AND DISCUSSION

4.1 Particle Size and Polydispersity Index

The nanoemulsion showed uniform droplet distribution indicating stable formulation. Small droplet size ensures better skin penetration and therapeutic effectiveness.

Parameter	Result
Mean droplet size	98 nm
Polydispersity Index (PDI)	0.24

Table 3: Particle Size Analysis



Graph 1: Particle Size Distribution

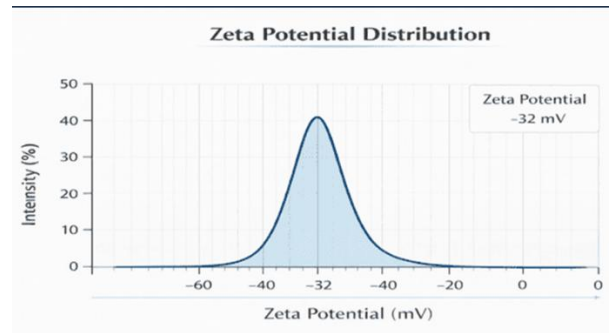
4.2 Zeta Potential

Zeta potential determines physical stability of nanoemulsion. High absolute value indicates good stability.

Table 4: Zeta Potential

Parameter	Result
Zeta potential	-32 mV

Table 4: Zeta Potential



Graph 2: Zeta Potential Distribution

4.3 Physicochemical Evaluation

Parameter	Result
pH	6.5
Viscosity	3850 cps
Spreadability	6.4 g·cm/sec
Appearance	Smooth transparent gel

Table 5: Physicochemical Properties

4.4 Drug Content

Sample	Drug content (%)
F1	97.2 %

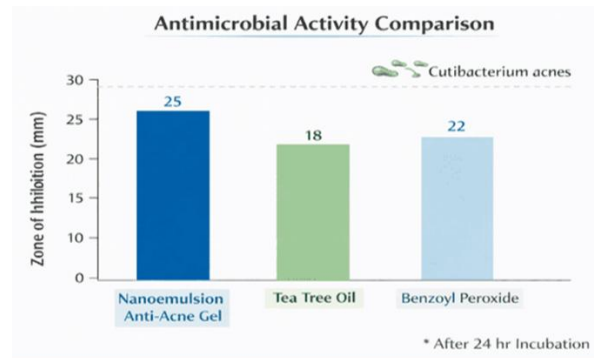
Table 6: Drug Content

4.5 Antimicrobial Activity

Nanoemulsion gel showed significant inhibition against acne-causing bacteria.

Sample	Zone of inhibition (mm)
Marketed gel	18
Nanoemulsion gel	24

Table 6: Drug Content



Graph 3: Antimicrobial Activity Comparison

4.6 Stability Study

Day	pH	Phase separation
0	6.5	Absent
15	6.5	Absent
30	6.4	Absent

Table 8: Stability Data

V. DISCUSSION

The nanoemulsion-based herbal anti-acne gel exhibited desirable physicochemical properties and stability. The droplet size below 100 nm confirmed efficient nanoemulsion formation. The negative zeta potential value indicated stable formulation due to electrostatic repulsion between droplets.

The antimicrobial activity of nanoemulsion gel was higher than marketed gel due to enhanced penetration and improved bioavailability of herbal constituents. Nano-sized droplets increased contact surface area and facilitated better diffusion through skin layers.

These results confirm that nanoemulsion technology significantly improves therapeutic efficiency of herbal anti-acne formulations.

VI. CONCLUSION

The present study successfully formulated and evaluated a nanoemulsion-based herbal anti-acne gel. The formulation showed small particle size, good stability, acceptable physicochemical properties, and enhanced antimicrobial activity.

The nanoemulsion gel demonstrated superior performance compared to conventional formulations and can be considered a promising topical drug delivery system for acne treatment.

Future Scope

- Clinical trials in acne patients
- Scale-up production
- Long-term stability study
- Commercial cosmeceutical product development

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